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F01 Vertical Dynamics Systems

Initial Print Date: 01/09 Revision Date:

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Vertical Dynamics Systems

Model: F01/F02

Production: From Start of Production

OBJECTIVES

After completion of this module you will be able to:

- Locate and identify components of the various Vertical Dynamics Systems
- Understand the operation of Vertical Dynamics Control
- Understand the operation of Active Roll Stabilization
- Understand the operation of Electronic Height Control

Introduction

New Generation of Familiar Systems

General
Nowadays, the dynamic handling systems are subdivided into three groups according to the co-ordinate axis that their function relates to.

Development continued over the years with the EDC II (E24) and EDC III (E31, E38 and E39) and ultimately the EDC-K ("K" stands for continuous) in the E65.

The E65 then became the first model to feature a new vertical dynamics system called **ARS** Active Roll Stabilization, which was marketed as "Dynamic Drive".

The existing vertical dynamics systems are also complemented by the **EHC** electronic ride-height control system which made its BMW debut on the E39 (air springs on 2 wheels) and E53 (air springs on all 4 wheels).

With the arrival of the E70 came an increasing level of system integration in the area of dynamic handling and for the first time a central control unit was used for the vertical dynamics systems which was called the **VDM** Vertical Dynamics Management unit.

With the new **VDC** Vertical Dynamics Control function, independent electronic damper control for each wheel was realized for the first time.

On the E70, and subsequently also on the E71, VDC was combined with ARS under the name of Adaptive Drive.

On the F01/F02, that constant development of the vertical dynamics systems has continued and the new generation of vertical dynamics management is referred to internally as **VDC II**.

System Overview

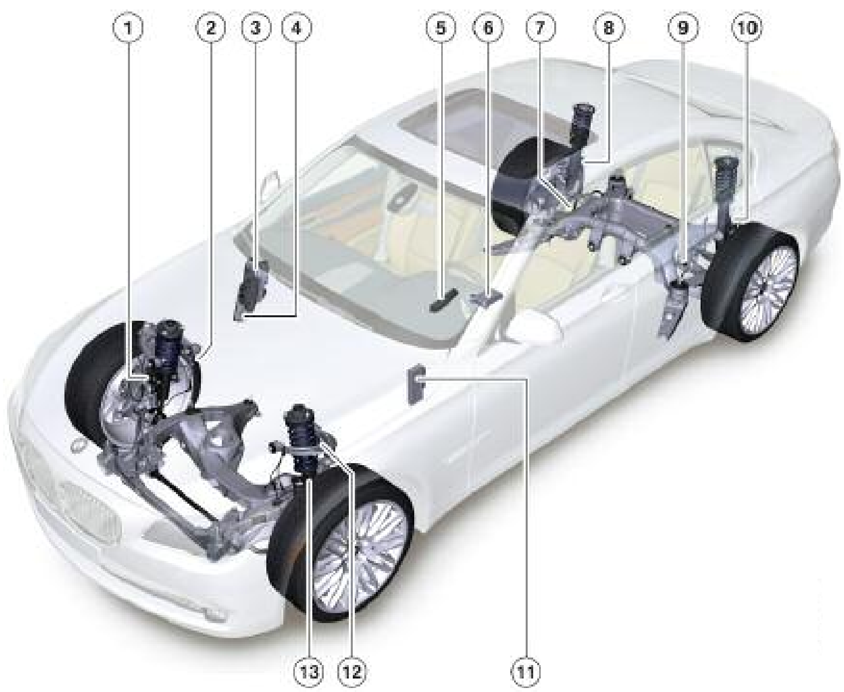
General

The following systems are available on the F01/F02:

- Electronic ride-height control (EHC)
- Active Roll Stabilization (ARS)
- Electronic ride-height control (EHC)

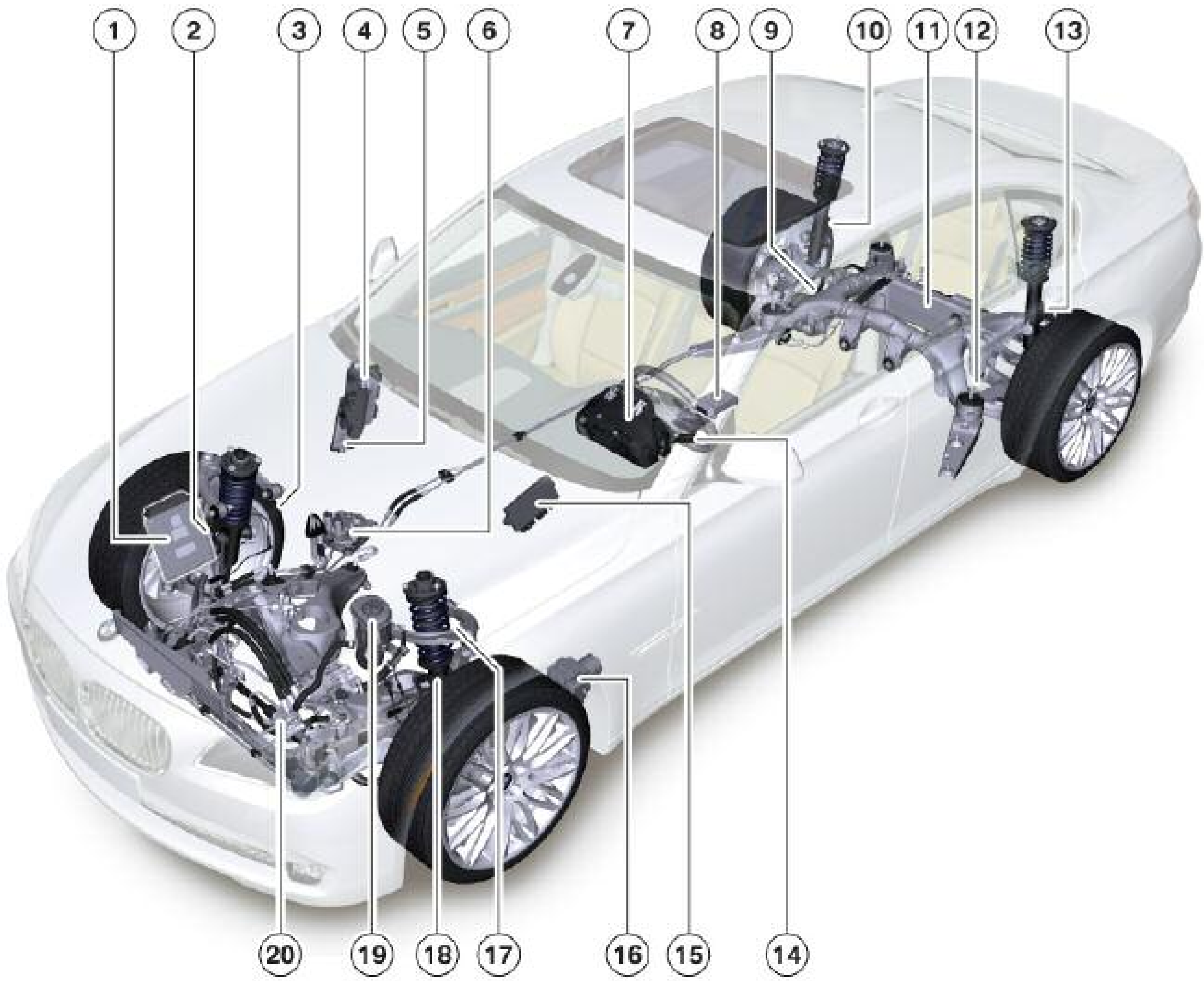
VDC (also called VDC II) is fitted as standard on the F01/F02. ARS and EHC are offered as optional extras on the F01, whereas EHC is standard on the F02.

Components of Vertical Dynamics Control (standard equipment)



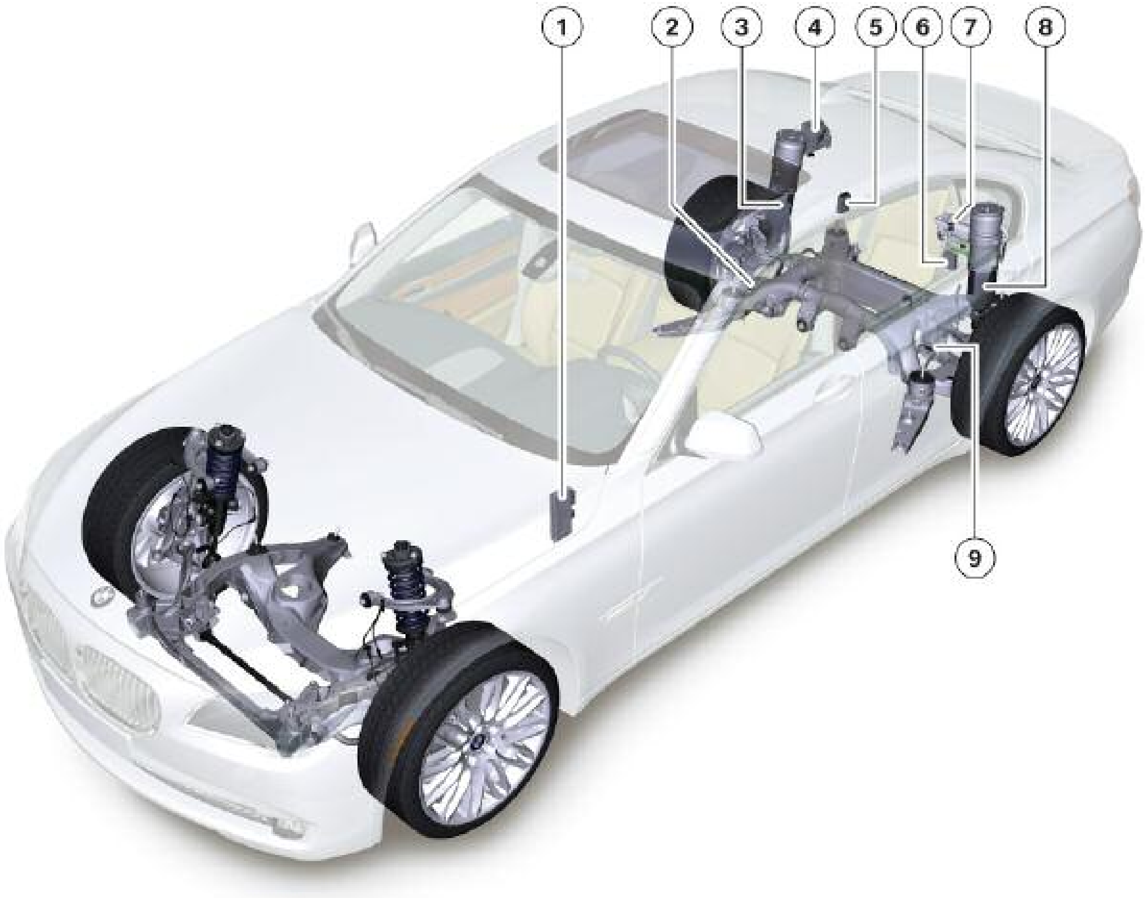
Index	Explanation	Index	Explanation
1	EDC_SVR	8	EDC_SHR
2	Ride-height sensor, front right	9	Ride-height sensor, rear left
3	Front power distribution box	10	EDC_SHL
4	VDM	11	ZGW
5	Handling setting switch	12	Ride-height sensor, front left
6	ICM	13	EDC_SVL
7	Ride-height sensor, rear right		

Components of Active Roll Stabilization with VDC



Index	Explanation	Index	Explanation
1	DME	11	Rear-suspension hydraulic motor
2	EDC_SVR	12	Ride-height sensor, rear left
3	Ride-height sensor, front right	13	EDC_SHL
4	Front power distribution box	14	SZL
5	VDM	15	ZGM
6	ARS valve manifold	16	DSC
7	Instrument cluster	17	Ride-height sensor, front left
8	ICM	18	EDC_SVL
9	Ride-height sensor, rear right	19	Hydraulic fluid reservoir
10	EDC_SHR	20	Front-suspension hydraulic motor

Components of electronic ride-height control



Index	Explanation	Index	Explanation
1	ZGM	6	Air supply relay
2	Ride-height sensor, rear right	7	LVA, air supply unit
3	EDC_SHR	8	EDC_SHL
4	Rear power distribution box	9	Ride-height sensor, rear left
5	EHC		

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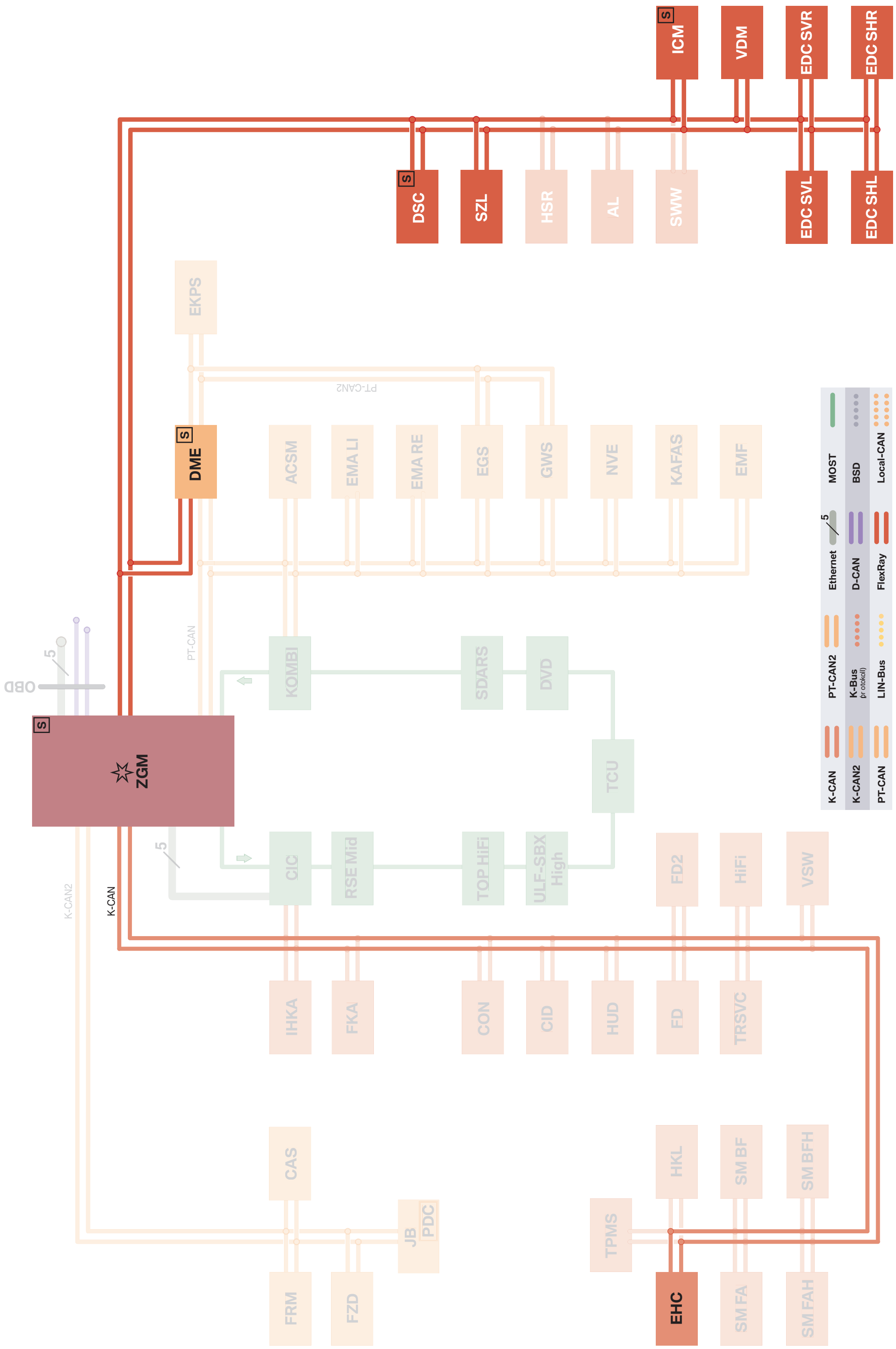
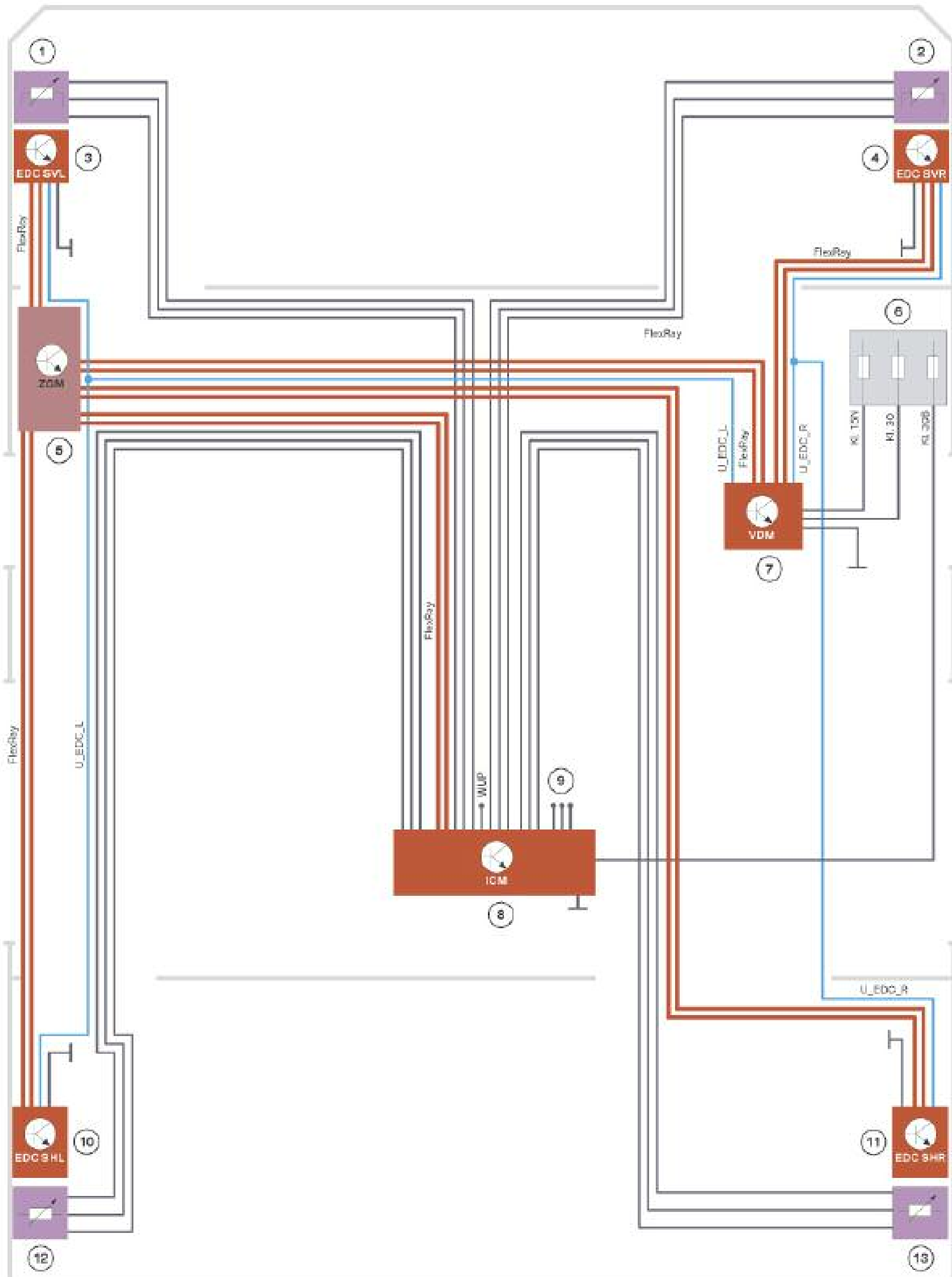
Bus System Overview for Vertical Dynamics Systems



Index	Explanation	Index	Explanation
EHC	Electronic ride-height control	VDM	Vertical Dynamics Management
ZGM	Central Gateway Module	EDC SVL	Electronic Damper Control satellite, front left
DME	Digital Motor Electronics	EDC SHL	Electronic Damper Control satellite, rear left
DSC	Dynamic stability control	EDC SVR	Electronic Damper Control satellite, front right
SZL	Steering column switch cluster	EDC SHR	Electronic Damper Control satellite, rear right
ICM	Integrated Chassis Management		

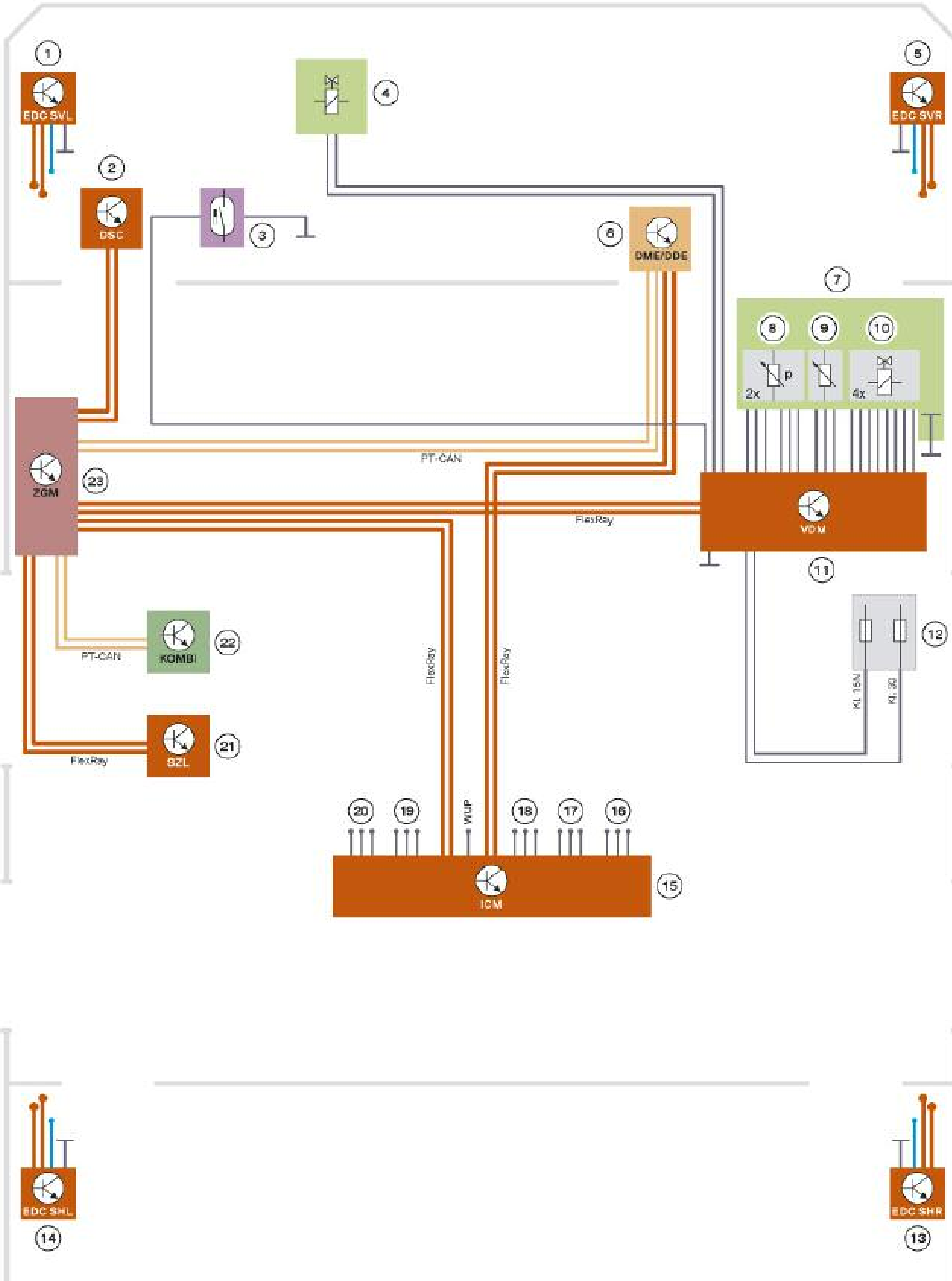
System Circuit Diagrams

VDC System Circuit Diagram



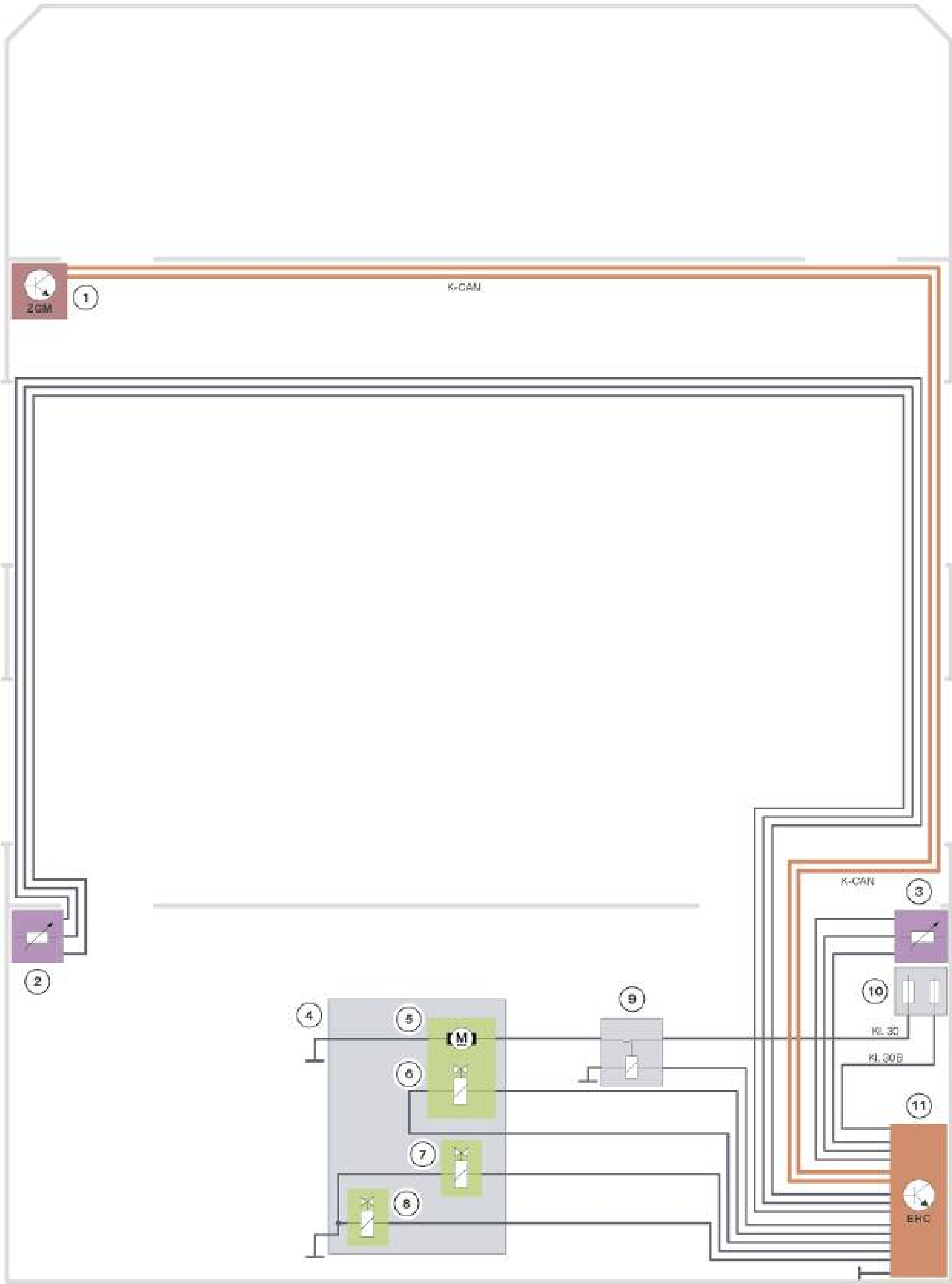
Index	Explanation	Index	Explanation
1	Ride-height sensor, front left	8	Integrated Chassis Management
2	Ride-height sensor, front right	9	Connection for handling setting switch
3	Electronic Damper Control satellite, front left	10	Electronic Damper Control satellite, rear left
4	Electronic Damper Control satellite, front right	11	Electronic Damper Control satellite, rear right
5	Central Gateway Module	12	Ride-height sensor, rear left
6	Front power distribution box	13	Ride-height sensor, rear right
7	Vertical Dynamics Management		

VDC and ARS System Diagram



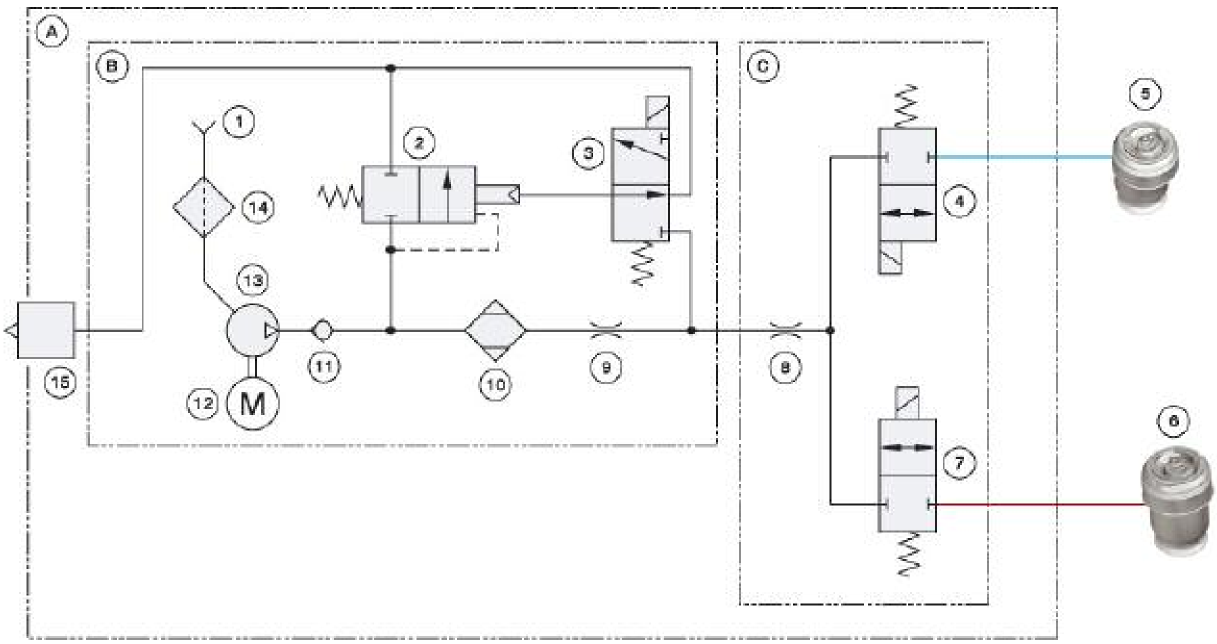
Index	Explanation	Index	Explanation
1	Electronic Damper Control satellite, front left	13	Electronic Damper Control satellite, rear right
2	Dynamic Stability Control	14	Electronic Damper Control satellite, rear left
3	Hydraulic fluid level sensor	15	Integrated Chassis Management
4	Intake restrictor valve	16	Ride-height sensor, rear left
5	Electronic Damper Control satellite, front right	17	Ride-height sensor, front left
6	Digital Motor Electronics/Digital Diesel Electronics	18	Ride-height sensor, front right
7	ARS valve manifold	19	Ride-height sensor, rear right
8	Front suspension pressure sensor/ rear suspension pressure sensor	20	Connection for handling setting switch
9	Switch-position detector	21	Steering column switch cluster
10	Failsafe, directional control and pressure valves	22	Instrument cluster
11	Vertical Dynamics Management	23	Central Gateway Module
12	Front power distribution box		

EHC System Diagram



Index	Explanation	Index	Explanation
1	Central Gateway Module	7	Solenoid valve, right side
2	Ride-height sensor, rear left	8	Air exhaust valve
3	Ride-height sensor, rear right	9	Air supply relay
4	Air supply unit	10	Rear power distribution box
5	Compressor unit	11	Electronic ride-height control
6	Solenoid valve, left side		

EHC Pneumatics Diagram



Index	Explanation	Index	Explanation
A	LVA, air supply unit	7	Solenoid valve, left side
B	Compressor unit	8	Restrictor
C	Solenoid valve block	9	Restrictor
1	Air intake (by left rear light unit)	10	Air drier
2	Pressure limiting/holding valve	11	Non-return valve
3	Air exhaust valve	12	Electric motor
4	Solenoid valve, right side	13	Compressor
5	Air spring, rear right	14	Air cleaner
6	Air spring, rear left	15	Air exhaust silencer

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Active Roll Stabilization (ARS)

General Information

Active Roll Stabilization was first fitted on the 7 Series predecessor, the E65/E66, and has been used in similar form since on the E6x and E7x models.

This section only describes the essential details and modifications of the ARS on the F01/F02.

As Vertical Dynamics Control (VDC) is fitted as standard on the F01/F02, the ARS optional extra (now also available in the US markets) is always offered as a combination.

In customer communications, ARS continues to be marketed under the name “Dynamic Drive” on the F01/F02.

System Dynamics

VDC and ARS have to respond with the appropriate speed in the event of rapid lane changes, rapid cornering or rapid changes of direction on winding country roads.

The ARS systems on previous model series had a separate control unit with the appropriate output stages for controlling the ARS valve manifold. The system architecture on the F01/F02 now features two different vertical dynamics management (VDM) control units:

- If ARS is not fitted, the VDM has no output stages for ARS valve manifold control
- If ARS is fitted, the VDM has output stages for ARS valve manifold control

The system dynamics of ARS and VDC are determined by the duration of the following stages:

Process	Time
Signal detection by sensors, processing of sensor signals in the control unit, valve control	approximately 10 ms
Change of direction, reversal of force direction, directional control valve	approximately 30 ms
Pressure increase (force per wheel) 0 -> 30 bar (0 -> 350 N) 0 -> 180 bar (0 -> 2100 N)	 approximately 120 ms approximately 400 ms

Operating States

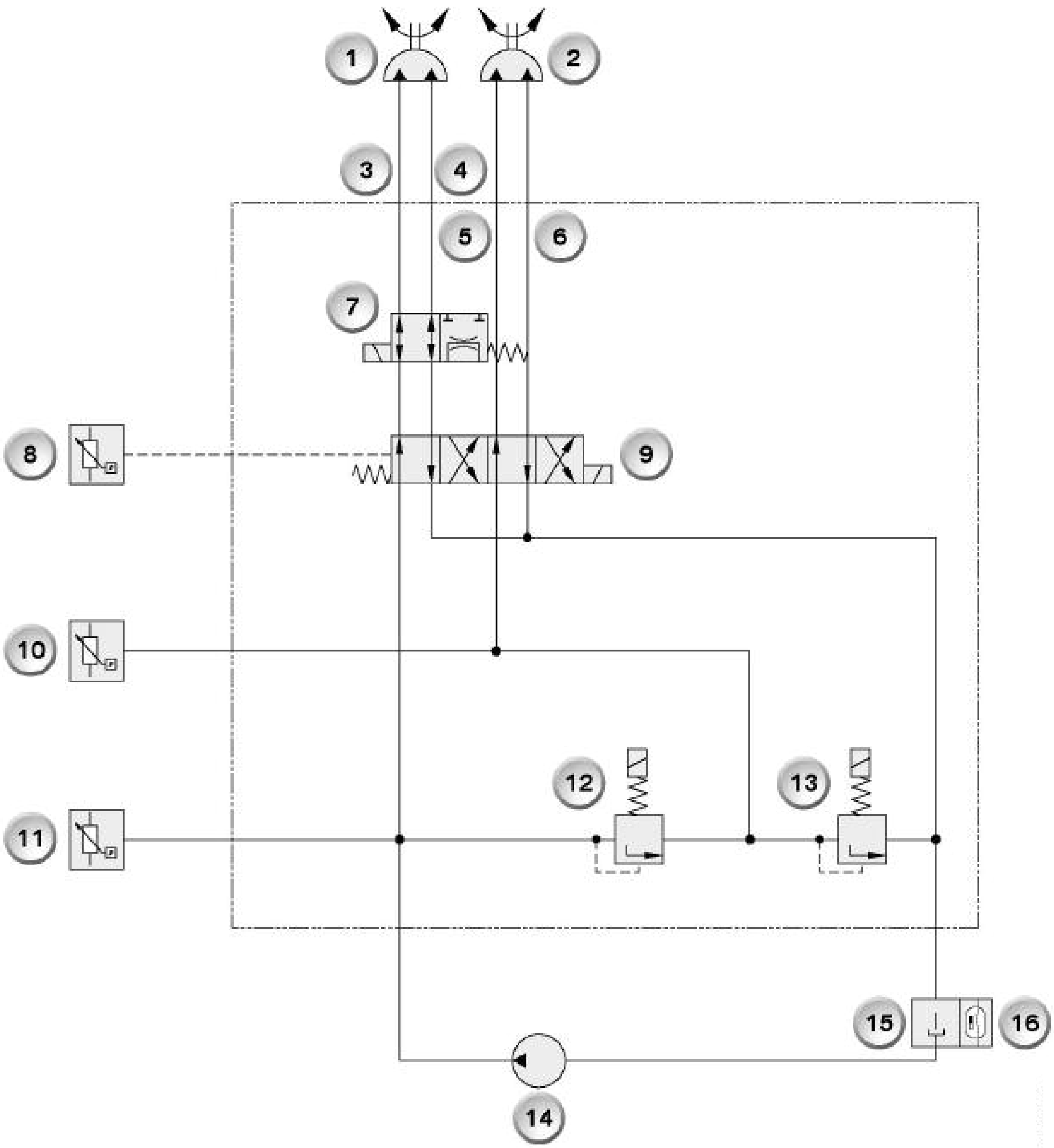
Straight-ahead travel
When the engine is started, the pump delivers hydraulic fluid to the system and a back pressure builds up. The pressure difference of approximately 1 bar which exists between the chambers of the control motor is very small and has no effect on the anti-roll bar.

The pressure valves for the front-axle anti-roll bar (PVV) and rear-axle anti-roll bar (PVH) are not supplied with current and are therefore open. The hydraulic fluid can flow back into the fluid reservoir directly. The pump's new intake restrictor valve is energized so that the circulation pressure can be substantially lowered when driving in a straight line in order to reduce CO2 emission. This condition remains unchanged as long as the vehicle is travelling straight ahead. The system function is displayed continuously up to 10 mph. The full stabilization capacity is available from 10 mph upwards.

Cornering
As the vehicle enters a bend, the signals from the lateral acceleration sensor in the ICM are sent to the VDM control unit. The control unit then sends a pulse-width modulated (PWM) signal to the pressure valves for the front and rear-suspension hydraulic motors and simultaneously stops restriction of pump intake by switching off the power to the intake restrictor valve. The greater the lateral acceleration, the higher is the PWM signal current for the pressure valves. The stronger the current supplied to the valve, the more the valve closes and the higher the pressure which builds up in the anti-roll bars.

The pressures at the anti-roll bars are detected by pressure sensors (10, 11) and signalled to the control unit. The direction valve (9) is activated by the control unit to create a pressure build-up which corresponds to the progression of the bend (left or right-hand bend). A sensor (8) detects the switching position of the direction valve.

Hydraulic circuit diagram, normal function - failsafe valve supplied with current



Index	Explanation	Index	Explanation
1	Front hydraulic motor (SMV)	9	Directional control valve (RV)
2	Rear hydraulic motor (SMH)	10	Rear-suspension pressure sensor (DSH)
3	Front-suspension hydraulic circuit 1 (V1)	11	Front-suspension pressure sensor (DSV)
4	Front-suspension hydraulic circuit 2 (V2)	12	Front-suspension pressure valve (PVV)
5	Rear-suspension hydraulic circuit 1 (V1)	13	Rear-suspension pressure valve (PVH)
6	Rear-suspension hydraulic circuit 1 (V1)	14	Tandem pump (P)
7	Failsafe valve (FS)	15	Fluid reservoir (HB)
8	Switch-position detector (SSE)	16	Fluid level sensor

Safety Concept

General information

The safety concept prevents malfunctioning of the system by monitoring signals and responds in a defined manner to faults caused by external problems on interfacing units or systems. System monitoring essentially comprizes of the following monitoring functions:

- Monitoring of the power supply voltage
- Monitoring of the electrical circuits for the valves and sensors within the system
- Monitoring of FlexRay bus communication and checking signal plausibility
- Monitoring hydraulic function when the vehicle is in motion and predrive test

If a fault is detected, a defined response is initiated according to the significance of the fault (function impairment). The VDM control unit records the fault in the fault memory and displays the response on the instrument cluster.

Limited function (fall-back level)

If a system fault has been detected which allows continued operation of the system with limited functionality, this is indicated together with a warning message

ARS indicator lamp (yellow)

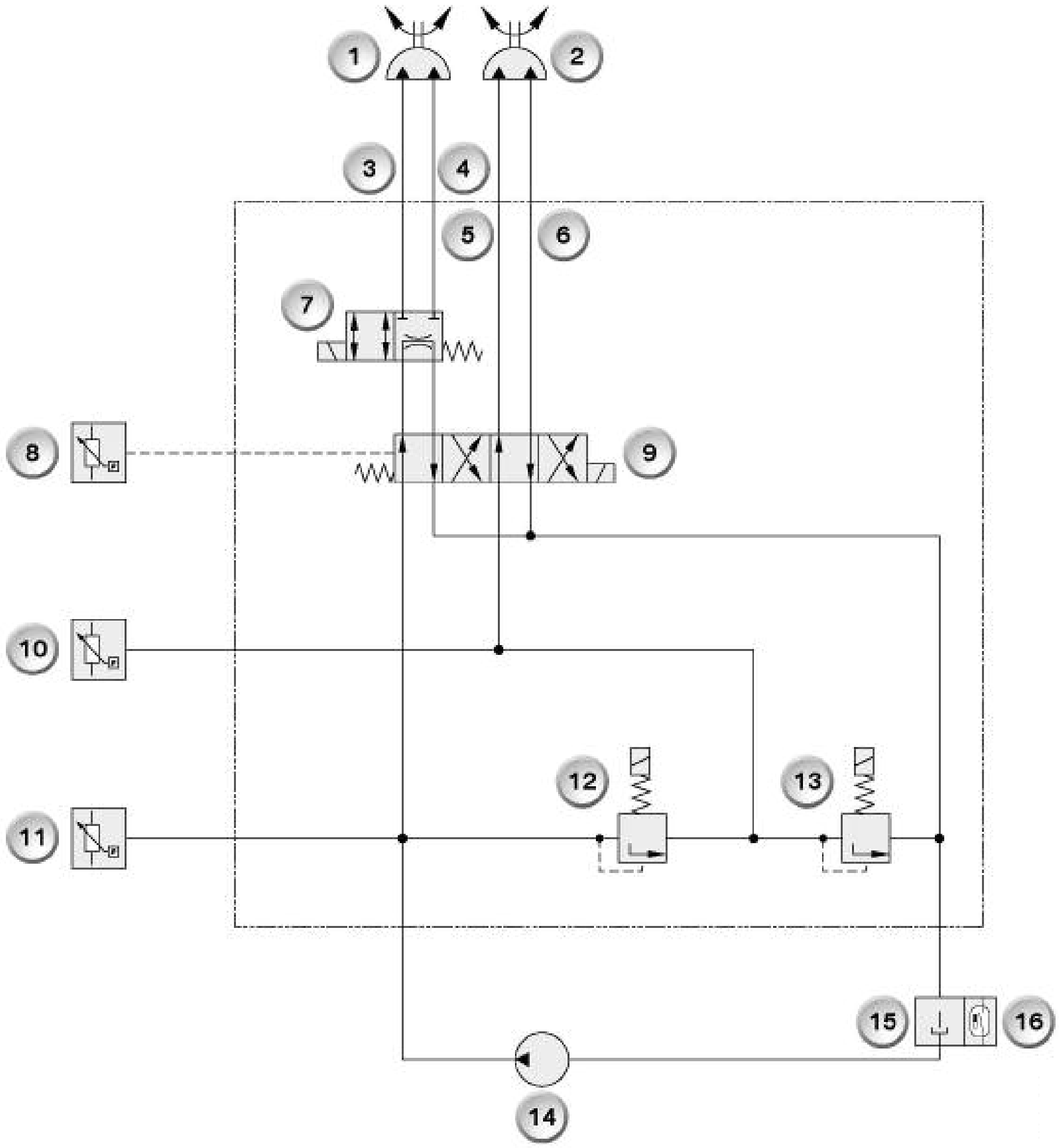
Serious fault (fall-back level)

If a serious fault is detected, the ARS system is set to “failsafe mode” and this is indicated on the instrument cluster. A CC message advises the driver to take corners more slowly.

ARS indicator lamp (yellow)

If the failsafe condition is activated, the failsafe valve is closed by means of a spring. The hydraulic fluid in the front anti-roll bar is sealed in, thereby ensuring an adequate anti-roll effect and an understeer effect equivalent to that of a conventional suspension and steering system. The failsafe situation is shown by the hydraulic circuit diagram below.

Failsafe function or neutral position hydraulic circuit diagram



Index	Explanation	Index	Explanation
1	Front hydraulic motor (SMV)	9	Directional control valve (RV)
2	Rear hydraulic motor (SMH)	10	Rear-suspension pressure sensor (DSH)
3	Front-suspension hydraulic circuit 1 (V1)	11	Front-suspension pressure sensor (DSV)
4	Front-suspension hydraulic circuit 2 (V2)	12	Front-suspension pressure valve (PVV)
5	Rear-suspension hydraulic circuit 1 (V1)	13	Rear-suspension pressure valve (PVH)
6	Rear-suspension hydraulic circuit 1 (V1)	14	Tandem pump (P)
7	Failsafe valve (FS)	15	Fluid reservoir (HB)
8	Switch-position detector (SSE)	16	Fluid level sensor

Fluid loss due to external leakage
The hydraulic circuits of the ARS system and the steering system are linked to one another by virtue of a shared fluid reservoir. The VDM control unit monitors the fluid level in the reservoir by means of a fluid level sensor. Loss of fluid due to external leakage in the hydraulic circuits of the ARS or steering systems leads to a drop in the fluid level in the shared fluid reservoir. Fluid loss can result in total failure of the ARS system and impairment of the steering system. If the fluid level sensor trips, the ARS system is set to failsafe mode and a fault is registered on the VDM control unit.

ARS indicator lamp (red)

Simultaneously, a CC message is issued warning of impairment of ARS system and steering system function. The driver is instructed to carefully bring the vehicle to a halt and switch off the engine.

Initialization/reset performance
When the VDM control unit is booted up, various checks and initialization routines are executed. They include checks of the electrical circuits for the valves and the sensors within the system, an authentication check involving querying the VIN number on the CAS and testing FlexRay communication. The system is not enabled until the tests have been successfully completed. Occurring faults are stored and displayed.

Predrive test
Every time the engine is started or the vehicle is stopped, an automatic quick test of the hydraulic function of the failsafe valve and front-suspension pressure regulating valve is carried out which lasts only 450 ms and is imperceptible to the driver. That test is only started when the engine is running and the vehicle is stationary, provided no other fault is present. If the predrive test identifies a fault, the appropriate fault response is initiated.

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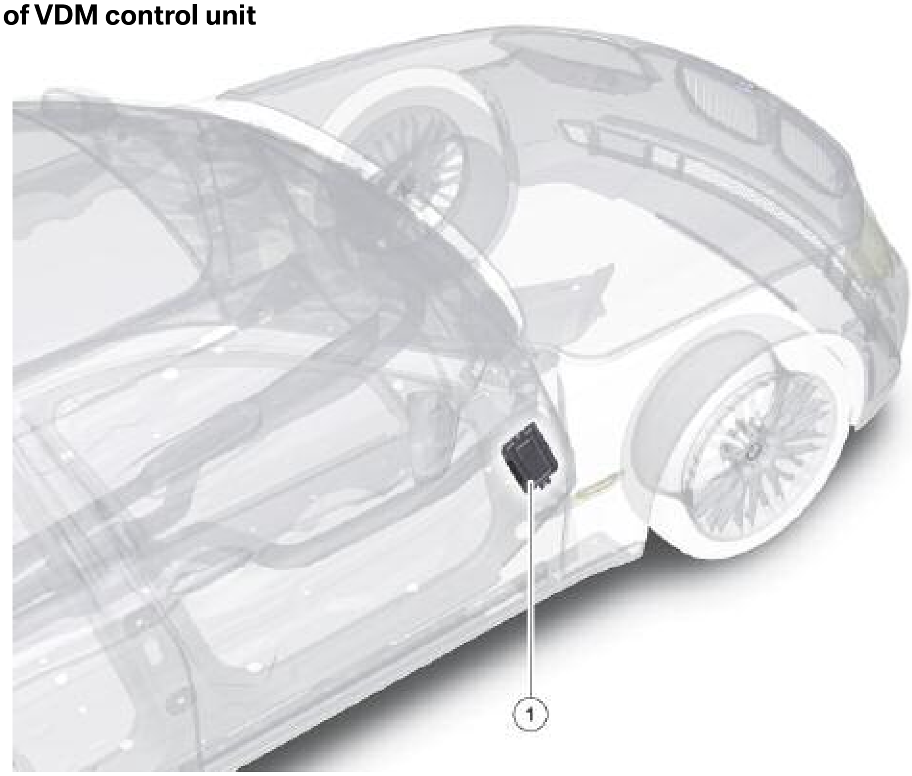
Components

Active Roll Stabilization (ARS)

Control Unit

The VDM control unit is located in the passenger compartment near the right-hand A-pillar. The VDM control unit receives its power supply via Terminal 15N and is protected by a 5A fuse. The VDM control unit is activated exclusively by the Car Access System (CAS) via a Terminal 15N lead as of status "Ignition ON".

Location of VDM control unit



Index	Explanation
1	VDM control unit

A vehicle authentication process takes place when the system is started. This compares the vehicle identification number from the CAS with the vehicle identification number which is encoded on the VDM control unit.

That is followed by a check of the VDM control unit's hardware and software. All outputs (valve solenoids and sensors) are subjected to a comprehensive check for short circuits and circuit breaks. If there is a fault, the system switches the actuators to a safe-driving mode.

The VDM control unit switches off if the voltage is too low/too high.

VDM control unit inputs

From the input signals, the VDM control unit calculates the control signals to the actuators. The input signals are also checked for plausibility and used for system monitoring.

The VDM control unit receives the following input signals:

- FlexRay bus
- Front-suspension circuit pressure (analog)
- Rear-suspension circuit pressure (analog)
- Switch position detector reading (analog)
- Fluid level sensor signal (analog)

The most important control signal for the ARS function is the lateral acceleration measured by the ICM control unit, which is sent to the VDM via the FlexRay bus. Additional lateral dynamics information from the FlexRay bus which is also provided by the ICM comprizes the road speed signal and the steering angle. From that, the stabilization requirement is calculated and the relevant active forces are applied. The road speed and steering angle information is also used to improve the reaction time of the system.

VDM control unit outputs

All outputs are compatible with diagnostics and protected against short-circuit. The outputs include controls for:

- Pressure regulating valves for front and rear axle
- Failsafe valve
- Directional valve
- Intake restrictor valve
- 5 V power supply for the sensors:
  - Pressure sensors at the front and rear axle
  - Switch-position detector (SSE)

The valves are controlled by the supply of current regulated by pulse-width modulation (PWM). The current measurements of the individual coil currents are designed with redundancy. The valve currents are mutually checked for plausibility on a continuous basis.

Thanks to the current measurement, the pressure can be set more precisely and the switch valves can be monitored electronically. Fault symptoms of the output signals are:

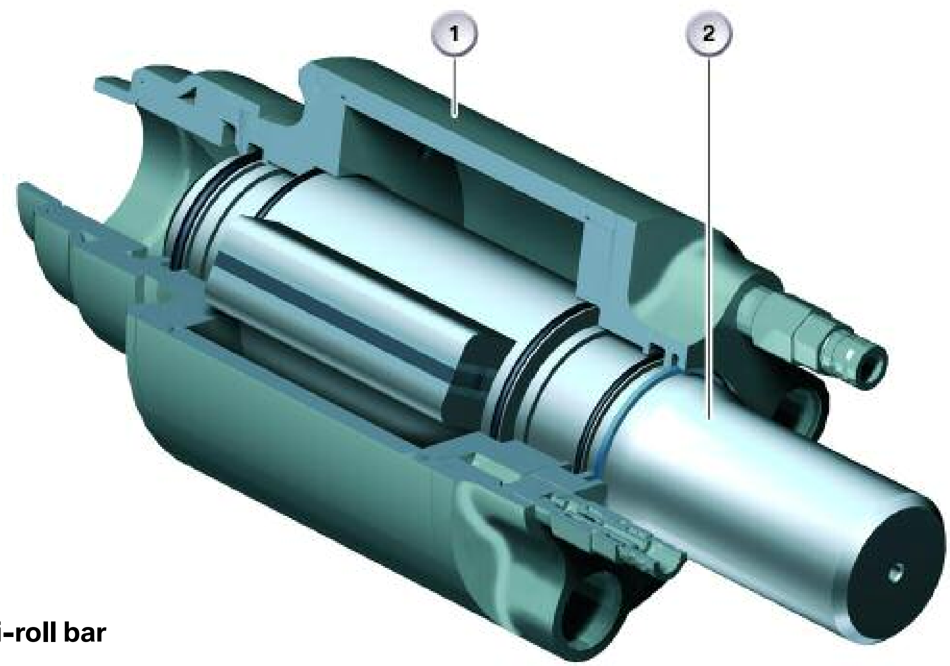
- Short circuit to Terminal 30 and Terminal 31
- Open circuit and
- Valve short circuits
- Sensor power supply faults

A message is sent to the DME via the FlexRay bus from the central dynamic handling controller on the ICM. The message contains information on how much power the tandem pump currently requires to supply the active anti-roll bars. In this way, output at the engine can be increased to satisfy the additional power requirement. A regular data signal (alive signal) is broadcast and read by other VDM control units to identify whether the system is still active. In addition, a function status signal is broadcast which communicates the status of the ARS function. The VDM control unit transmits an additional status message via the FlexRay to the instrument cluster in order to actively initiate display messages.

That status message is assigned a priority among all suspension/steering messages by the message co-ordinator on the ICM control unit and passed to the instrument cluster. All signal faults are recorded and permanently stored in the fault memory. If the alive signal fails, the ICM control unit automatically sends a message to the instrument cluster to activate the ARS warning lamp.

ARS indicator lamp (red)

Oscillating Motor



Active anti-roll bar

Index	Explanation	Index	Explanation
1	Oscillating motor housing	2	Oscillating motor shaft

The hydraulic motor and the hydraulic motor body are each attached to one half of the anti-roll bar. The active anti-roll bar consists of the oscillating motor and the anti-roll bar halves fitted to the oscillating motor, with press-fitted roller bearings for their connection to the axle carriers. The use of roller bearings ensures optimum comfort thanks to better response and reduced control forces. A thin coating of grease on the roller bearing does not impair the function of the active anti-roll bar.

Operating principle of oscillating motors

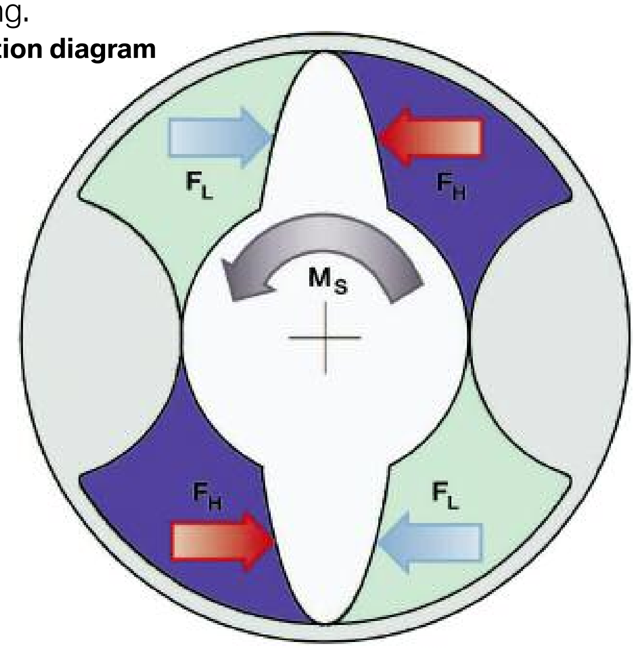
The oscillating motor has three functions to perform:

- The oscillating motor transfers the torque into the anti-roll bars.
- The hydraulic motor isolates the two halves of the anti-roll bar
- In the event of system failure (failsafe mode), the front axle anti-roll bar creates sufficient damping via the oscillating motor hydraulic fluid (hydraulic locking). The front suspension anti-roll bar then works like a conventional anti-roll bar.

Exception: if the hydraulic motor chambers no longer contain any fluid as a result of a leak, the front suspension anti-roll bar cannot provide a damping force. The opposing chambers in the oscillating motor are connected to one another. The same pressure exists in both chambers. Two chambers are supplied with high-pressure fluid using one connection. The two other chambers are connected to the tank via the return line.

The forces F_H (High) or F_L (Low) are created as a result of the differences in pressure. Since F_H is greater than F_L, a torque M_S is produced, which causes the shaft to turn in relation to the housing.

Oscillating motor section diagram



Since one half of the stabilizer bar is connected to the shaft, and the other with the housing, the two halves turn in opposite directions. This torque M_S generates the active moment M_A around the vehicle longitudinal axis via the anti-roll bar connections which counteracts the rolling moment M during cornering.

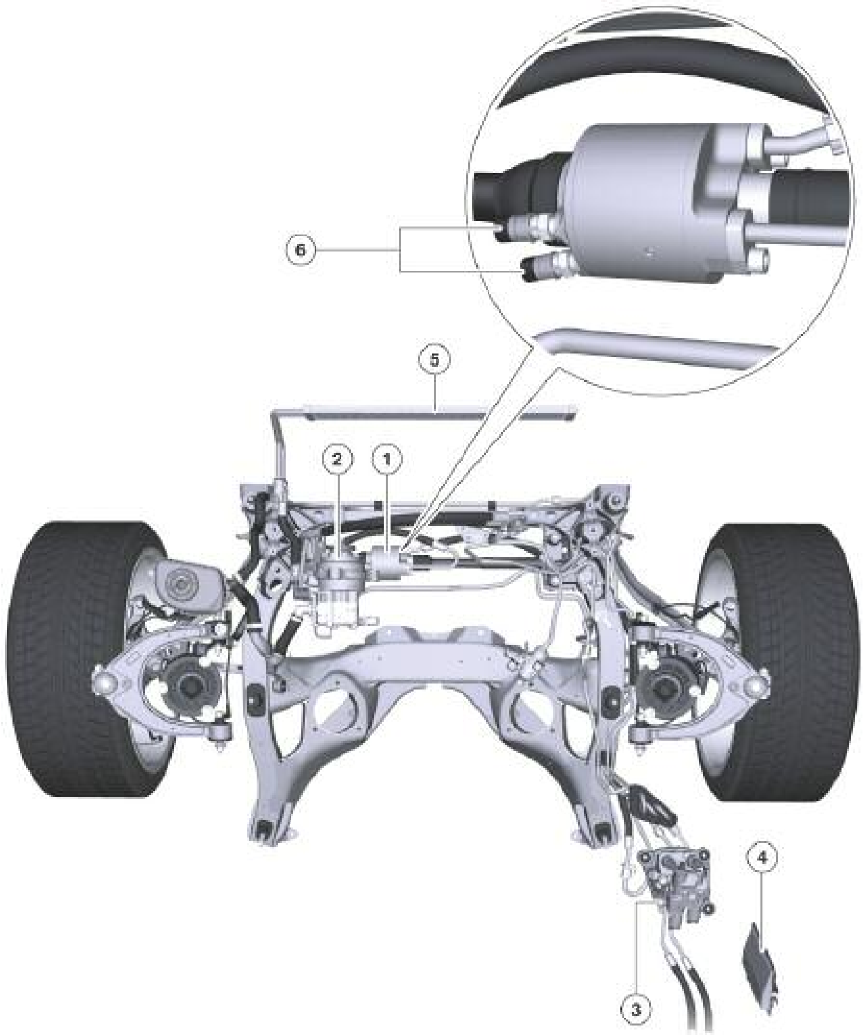
The shell is forced upwards on the outside of a curve, and dragged down on the inside of a curve. The maximum level of body torque on the front and rear suspension occurs when there is a high rate of lateral acceleration. The system pressure is then 180 bar on the front suspension and also 180 bar on the rear suspension. If the oscillating motor twists as a consequence of external forces (road excitation, e.g. bumps or potholes), the oscillating motor then acts as a torsional-vibration damper.

As a result of the twisting action, fluid is forced out of the two chambers. The displaced fluid flows through the pipes and the hydraulic valve manifold, the hydraulic resistance of which produces a damping effect. In the event of failsafe locking (hydraulic locking), the oscillating motor can only twist with a very high damping effect as a consequence of the hydraulic jamming in the oscillating motor.

Function of pressure relief valves

When the vehicle is driven on poor road surfaces, the movements of the anti-roll bar produce transient low pressures (cavitation) and pressure peaks in the hydraulic motors which can cause rattling noises. To prevent those noises, pressure relief valves and internal pulsation dampers have been fitted on the front hydraulic motor. The pressure relief valves allow filtered air to flow into the hydraulic motor to prevent cavitation. That small quantity of air is absorbed by the hydraulic fluid (Pentosin) to form an emulsion which is discharged in the course of subsequent operation of the hydraulic motor. The surplus air is separated out in the expansion tank.

Front Suspension Active Anti-roll Bar

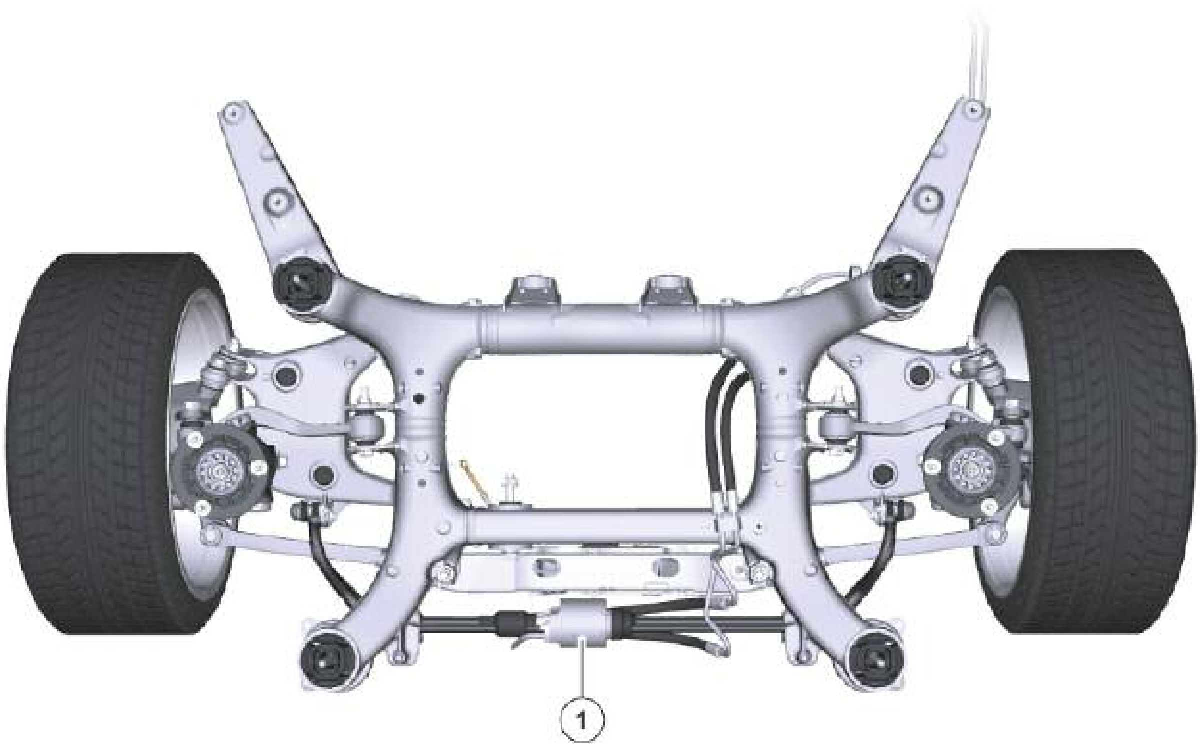


Index	Explanation	Index	Explanation
1	Front-suspension hydraulic motor	4	VDM
2	Tandem pump	5	Hydraulic cooler
3	ARS hydraulic valve manifold	6	Air filter element

The anti-roll bar is mounted on the front suspension subframe. The anti-roll bar links are attached to the pivot bearing. There are two pressure relief valves on the hydraulic motor of the front suspension anti-roll bar.

On the pressure relief valves there are air filter elements (black plastic caps) attached. Those black air filter caps with Goretex inserts must not be removed.

Rear Suspension Active Anti-roll Bar

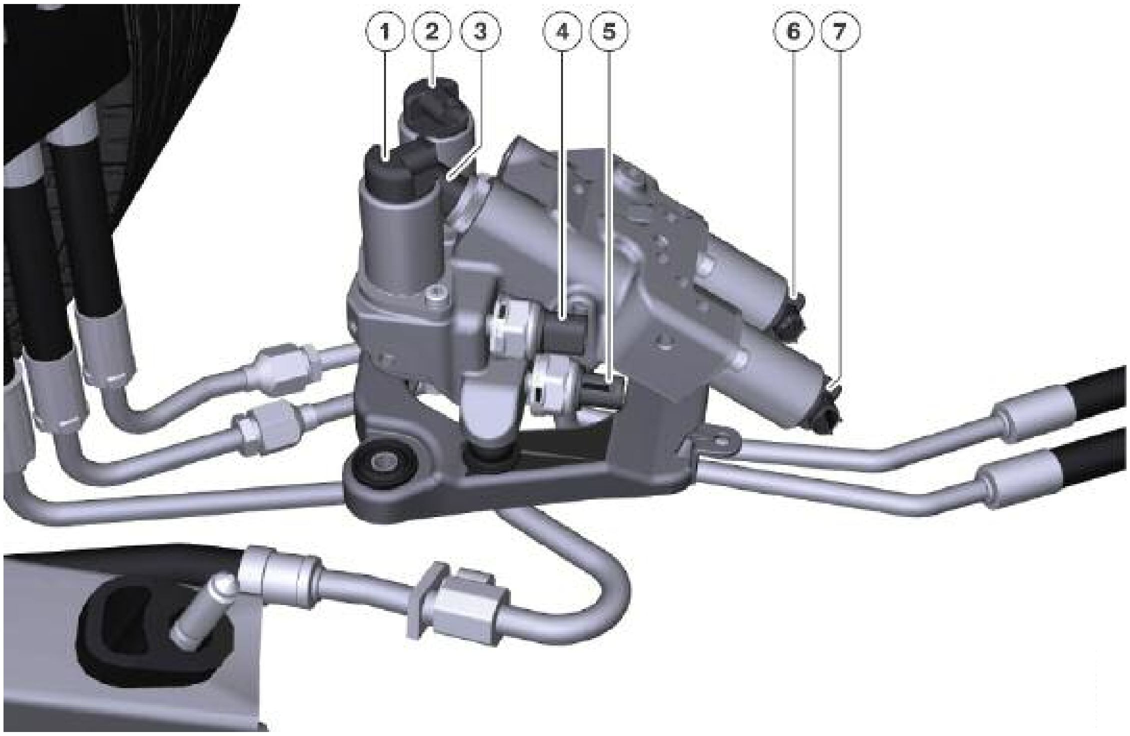


Index	Explanation
1	Rear suspension hydraulic motor

The anti-roll bar is mounted behind the rear suspension subframe. The anti-roll bar links are attached to the rear suspension swing arms.

On the hydraulic motor for the rear suspension anti-roll bar, blanking plugs are fitted in place of the pressure relief valves.

ARS Hydraulic Valve Manifold

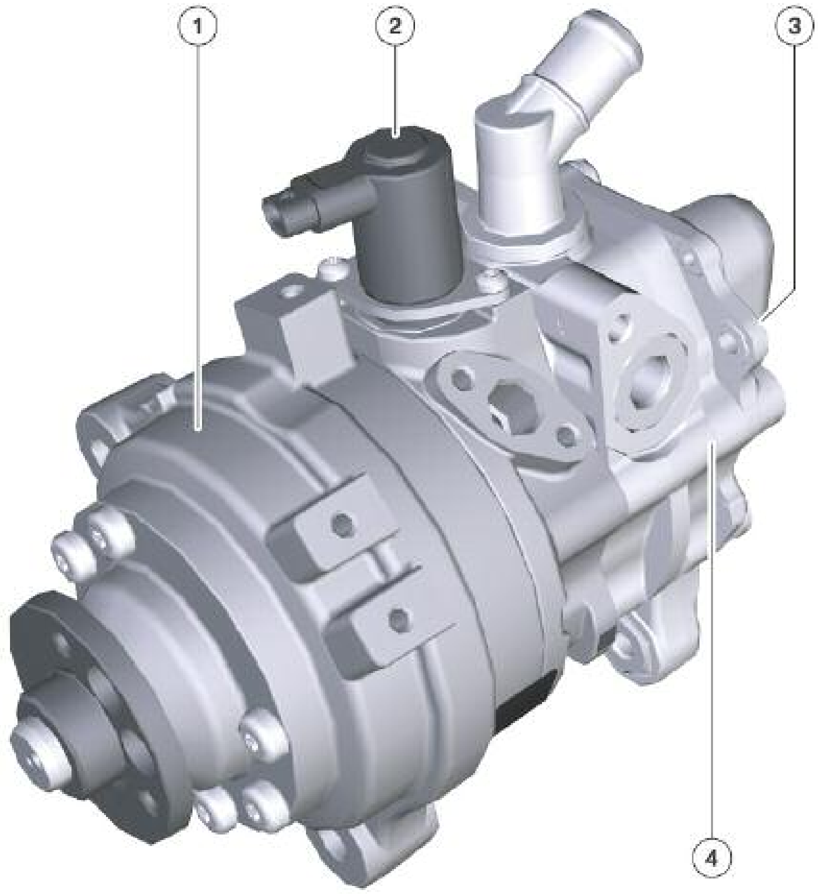


Index	Explanation	Index	Explanation
1	Front-axle pressure valve [PVV]	5	Rear-axle pressure sensor [DSH]
2	Rear-axle pressure valve [PVH]	6	Failsafe valve [FS]
3	Switch-position detector [SSE]	7	Direction valve [RV]
4	Front-axle pressure sensor [DSV]		

The hydraulic valve block is located on the floor plate of the vehicle behind the front right-hand wheel housing level with the front right- hand door. The hydraulic valve block is connected to a carrier plate bolted to the body. The hydraulic valve block houses the following valves and sensors:

- 2 pressure valves; 1 for the front suspension and 1 for the rear suspension [these are proportional pressure limiting valves]
- 1 directional control valve
- 1 failsafe valve
- 2 pressure sensors; 1 sensor for the front suspension, 1 sensor for the rear suspension
- Switch-position detector

Tandem Pump



Index	Explanation	Index	Explanation
1	Radial piston pump (ARS)	3	Electronic volumetric flow control (EVV) valve
2	Intake restrictor valve	4	Vane pump (power steering)

The hydraulic pumps fitted in this model series were based on a modular design principle. Depending on the engine and equipment specification, a suitably dimensioned hydraulic pump is flange-mounted to the engine in the same installation space. Decisive equipment features for these tandem pumps:

- Basic steering
- Integrated Active Steering (IAL)
- CO2 reduction measures
- Dynamic Drive (ARS)
- Dynamic Drive (ARS) and Integrated Active Steering (IAL)
- Intake restrictor valve

The hydraulic pump driven by the engine's poly-V belt is, on vehicles with Dynamic Drive, invariably a tandem pump, which consists of a radial-piston pump section for ARS and a vane pump section for the power steering.

Radial-piston pump section of the tandem pump

This radial piston pump has 8 pistons in a single row and is designed for a maximum pressure of 210 bar.

When the engine is idling, the pump speed is approximately 750 rpm. At that speed, the radial piston pump section delivers a minimum fluid flow rate of approximately 5.5 l/min at a pressure of approximately 3 bar. Consequently an adequate fluid flow rate is guaranteed even at idling speed.

At a pump speed of 1450 rpm, the maximum fluid flow rate is limited to approximately 9 l/min.

New feature

As a CO2 reduction measure when driving in a straight line, the fluid flow rate of the radial piston pump is restricted by a restrictor valve on the intake side, thereby substantially reducing the circulation pressure and, therefore, the engine power used to drive the pump. As a result, active control of the intake restrictor valve makes a positive contribution to the CO2 equation.

The Dynamic Drive and hydraulic power steering share a common fluid reservoir and fluid cooler.

Vertical Dynamics Control

General Information

When driven vigorously or on an uneven road surface, a vehicle tends to respond with undesirable body movements. BMW first developed Vertical Dynamics Control for the E70 and was able to effectively reduce such body motion as a result.

VDC improves the following driver-perception related vehicle characteristics according to road surface conditions:

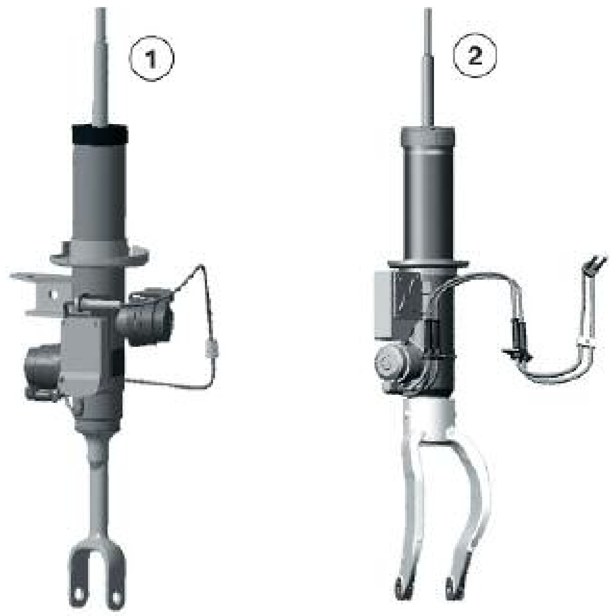
- Body-related ride comfort (primary ride comfort)
- Roadwheel-related ride comfort (secondary ride comfort)
- Dynamic handling (transitional response, agility) even with more comfortable suspension setting.

BMW is the first manufacturer to offer a damper adjustment system that is continuously controllable independently of damper compression/extension as is the case with the VDC (2) on the F01/F02.

The essential improvements compared with VDC (1) are:

- 1 EDC control valve for damper extension control
- 1 EDC control valve for damper compression control
- “Pre-opening adjustment” for improved body stabilization (has adjustment effect even at low damper rates)
- Driver-perceptible broad spread in conjunction with the handling setting switch (difference between soft and hard characteristics)
- Separately adjustable characteristic for roadwheel-related ride comfort (extension characteristic independent of compression characteristic)

VDC dampers



Index	Explanation	Index	Explanation
1	Front damper, VDC 2	2	Front damper, VDC 1

	VDC 1	VDC 2
Model	On E70/E71 included in Adaptive Drive Equipment package	Standard equipment in F01/F02
Program selection	Sport button next to gear selector	Handling setting switch next to gear selector
Program type	Sport/Comfort	Coordinated integration in all dynamic handling control functions
Control unit	VDM control module, right rear of luggage compartment 4 EDC satellite control modules directly on damper units	VDM control module, front right A-pillar 4 EDC satellite control modules directly on damper units
Damper	Twin tube, gas filled shock absorbers	Twin tube, gas filled shock absorbers
Fault diagnosis	VDM and EDC satellite control modules fully diagnosable	VDM and EDC satellite control modules fully diagnosable
Programming	VDM and EDC satellite control modules flash-programmable	VDM and EDC satellite control modules flash-programmable
Coding	VDM and EDC satellite control modules codable	VDM and EDC satellite control modules codable
Malfunction display	Messages in the Control Display or instrument cluster	Messages in the Control Display or instrument cluster
Testing	BMW diagnostic systems	BMW diagnostic systems

Signal Processing

- The vertical movement of the wheels is detected by the wheel-acceleration sensors integrated in the EDC satellite control units
- From the wheel acceleration rates and the ride height signals (FlexRay bus) the vehicle body motion is calculated
- In addition, signals such as the vehicle road speed are read from the FlexRay bus for the purpose of determining required damping forces.

Signal processing/VDC (2) controller
Individual damping forces are calculated for each individual wheel according to the vehicle body motion, the wheel motion and the additional signals read from the FlexRay bus, and are sent every 2.5 ms to the EDC satellite control units.

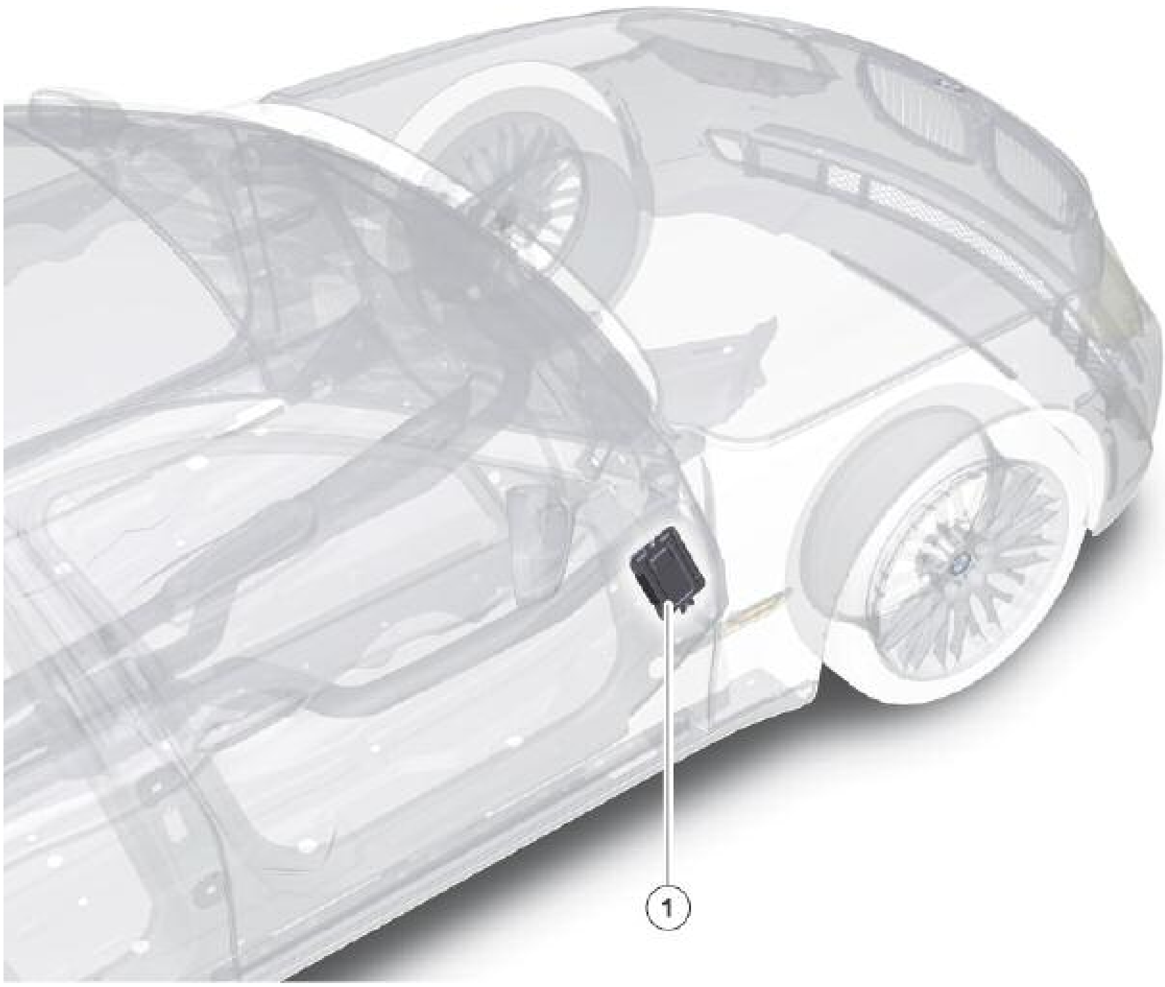
Damping Force Adjustment

- Stored on each EDC satellite control module is the actual individual damper characteristic, making it possible to minimize differences from the specified characteristic arising from manufacturing tolerances
- From the specified damping force and the damper characteristic data map, the EDC satellite control units calculate the required current to be applied to the damper extension valve and compression valve

NOTES PAGE

Vertical Dynamics Control (VDC)

Control Unit



Location of VDM

Index	Explanation
1	VDM

The location of the VDM control unit is dependent on the country in which the vehicle is sold.

- On left-hand drive vehicles the control unit is fitted inside the passenger compartment near the right A-pillar (as illustrated)
- On right-hand drive vehicles the control unit is fitted inside the passenger compartment near the left A-pillar

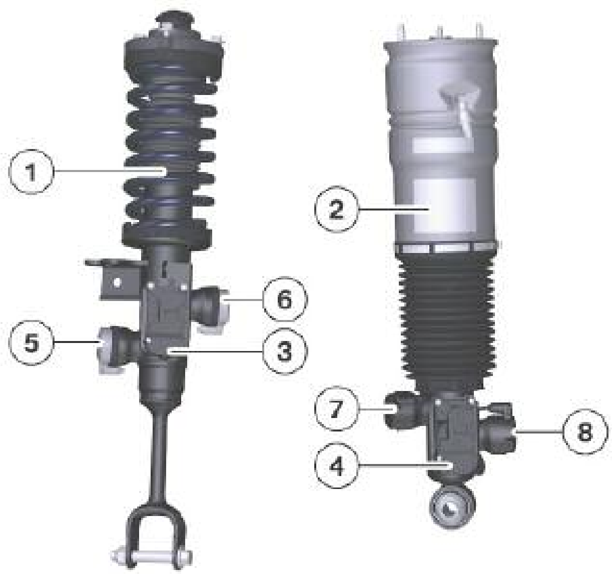
There are two different versions of the VDM control unit according to the equipment options fitted on the vehicle.

- The basic version of the VDM control unit is used if the vehicle has only the standard VDC equipment
- The high-spec version of the VDM control unit is used if, as well as the standard VDC system, the vehicle also has ARS Active Roll Stabilization (Dynamic Drive). In that case, the output stages for controlling the ARS valve manifold are also integrated in the VDM control unit.

EDC Satellite Control Unit with Damper

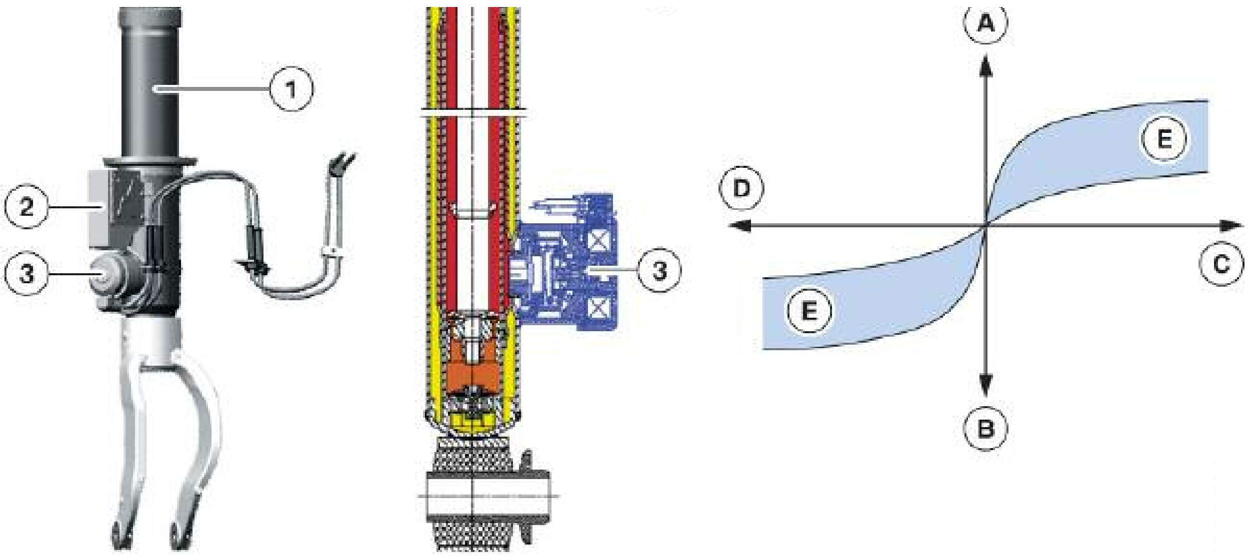
The VDC dampers on the rear suspension are either steel-spring or air-spring versions depending on the optional equipment fitted.

VDC damper versions



Index	Explanation
1	VDC damper with steel spring
2	VDC damper with air spring
3	Front EDC satellite control module
4	Rear EDC satellite control module
5	EDC data-map valve for compression control
6	EDC data-map valve for extension control
7	EDC data-map valve for extension control
8	EDC data-map valve for compression control

VDC (1) damper with one EDC data-map valve 12 -VDC (2) damper with two EDC data-map valves



Index	Explanation	Index	Explanation
1	Damper tube	B	FC = Compression force
2	EDC satellite control unit	C	VE = Extension velocity
3	EDC data-map valve for extension and compres-sion control	D	VC = Compression velocity
A	FE = Extension force	E	Extension and compression characteristic data map

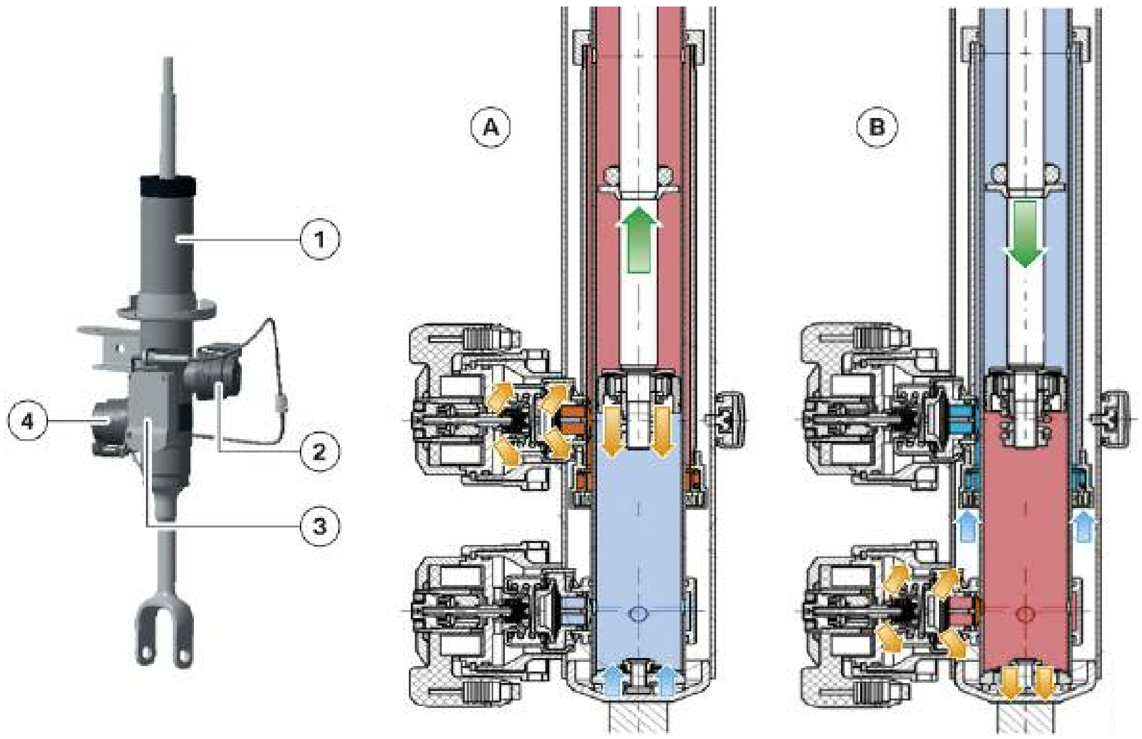
Difference between a VDC (1) and a VDC (2) damper:

A VDC (1) damper with only one EDC data map valve uses combined extension/compression adjustment which has to be cycled extremely rapidly.

With this type of control, the damper adjustment is based on wheel frequency.

The wheel frequency is the frequency at which the wheel oscillates along the z-axis.

VDC (2) damper with two EDC data-map valves



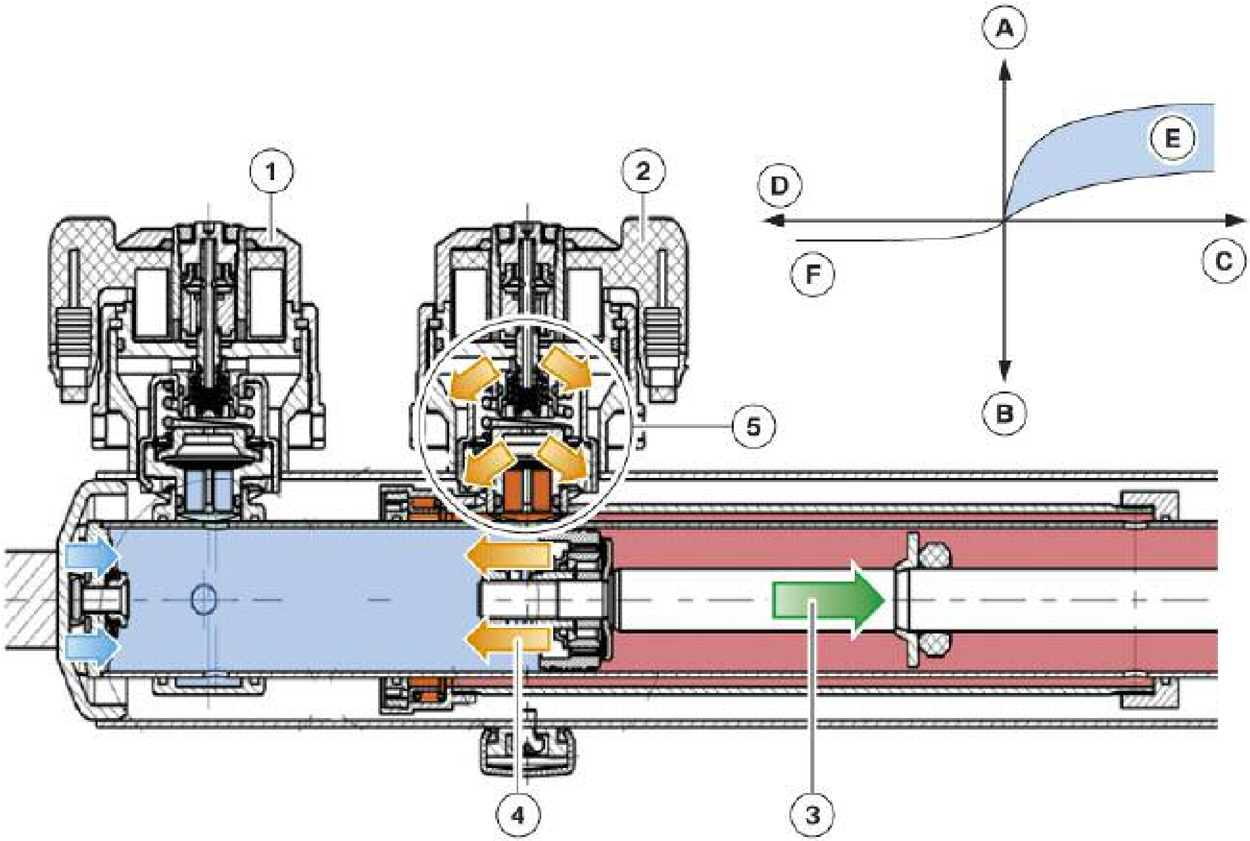
Index	Explanation	Index	Explanation
A	Extension progression	2	EDC data-map valve for extension
B	Compression progression	3	EDC satellite control unit
1	Damper tube	4	EDC data-map valve for compression

A VDC (2) damper with two EDC data-map valves uses independent extension/ compression adjustment which does not demand such a high cycling rate.

With this type of control, the damper adjustment can be based on body frequency.

The body frequency is the frequency at which the body oscillates along the z-axis.

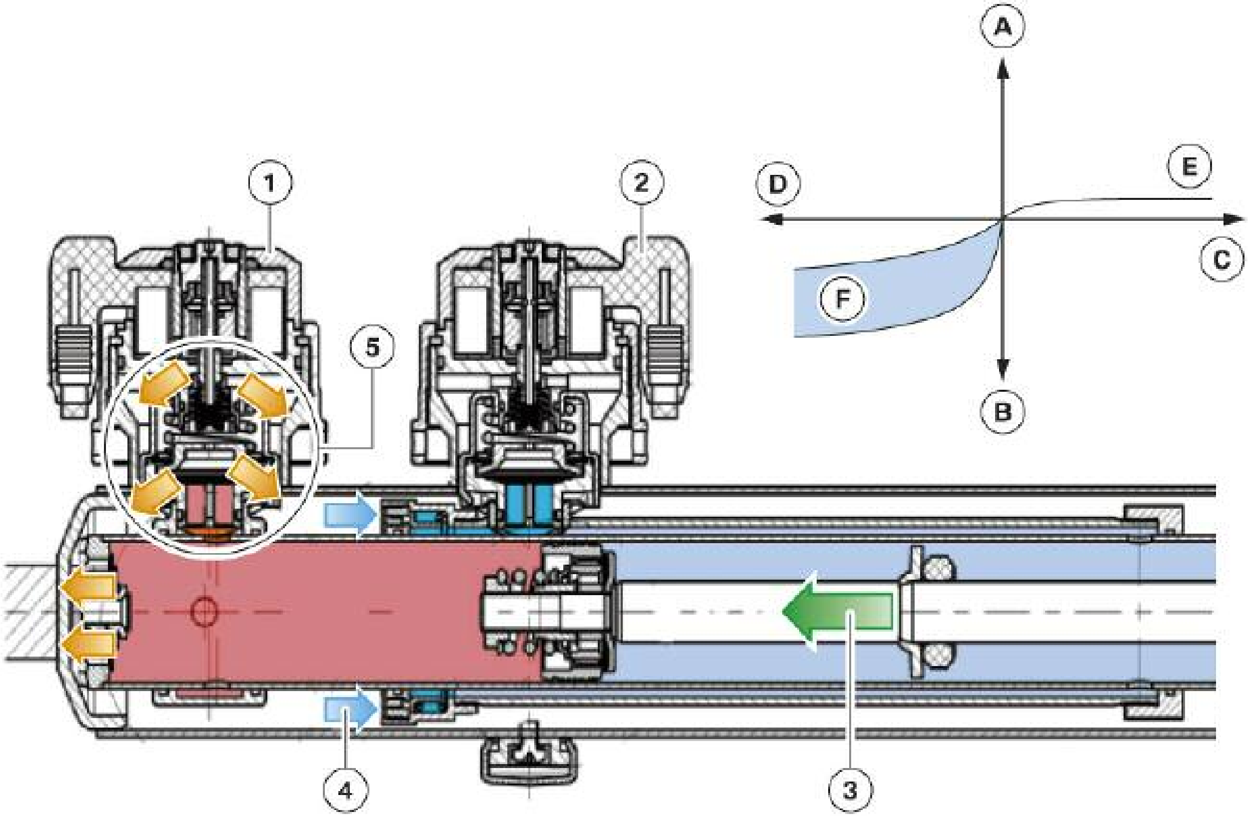
Fluid flow during extension



Index	Explanation	Index	Explanation
1	EDC data-map valve for compression	B	FC = Compression force
2	EDC data-map valve for extension	C	VE = Extension velocity
3	Force/direction of piston rod movement	D	VC = Compression velocity
4	Fluid medium	E	Extension data map
5	Data-map control	F	Compression data map
A	FE = Extension force		

The two EDC data-map valves firstly enable independent extension control and, therefore, data-map compatible design, and secondly independent compression control and, therefore, data-map compatible design.

Fluid flow during compression



Control strategy

The fundamental control principle is known as the "Skyhook system", the name of which reveals the primary control objective of holding the vehicle stationary in a vertical direction regardless of driving situation as if suspended from a "hook in the sky".

To achieve this highest of all comfort objectives, the movements of the entire body have to be evaluated. Thus an overall analysis is performed of the ride height data and z-axis acceleration rates.

Furthermore, VDC regulation takes into consideration steering inputs (e.g. transition from straight-ahead travel to cornering) based on the steering angle curve. If VDC detects a rapid increase in the steering angle, the controller infers that the vehicle is entering a bend and can preventively adjust the dampers on the outside of the bend to a harder setting in advance. Thus VDC assists the ARS system, if fitted, and contributes to reducing vehicle roll (roll tendency).

Moreover, VDC is able to detect the braking operations by the driver based on the brake pressure information supplied by DSC. A high brake pressure normally results in pitching of the vehicle body; VDC counteracts that effect by setting the front dampers to higher damping forces. This also results in an improvement in the front/rear brake force distribution, which in turn reduces the braking distance (by comparison with a vehicle without VDC).

On the E70/E71 with VDC (1), the “Sport” button for switching between comfort and sports setting only affected the VDC characteristics.

With the introduction of the handling setting switch, the VDC setting is incorporated in a number of modes which bring about a coordinated overall setting across all systems.

Ride-height Sensor

Index	Explanation
1	Electrical connector
2	Sensor housing
3	Lever

The angle of a pivoting lever is converted into a voltage signal by the ride height sensor. The greater the angle (relative to a defined starting or zero position), the greater is the output voltage. It is generated by a Hall-effect sensor element.

Designs

There are always four ride-height sensors fitted on all F01/F02 models.

The ride-height sensors fitted all operate according to the same principle but there are different designs (different part numbers). The reason for the differences are the available space and the starting position (zero position) of the individual ride-height sensors.

Depending on whether or not the vehicle is fitted with Electronic Height Control (EHC), double or single ride-height sensors are fitted on the rear suspension.

On the front suspension, single ride-height sensors are always used.

	Front suspension	Rear suspension
EHC, not fitted	Single RHS	Single
EHC, fitted	Single RHS	Double

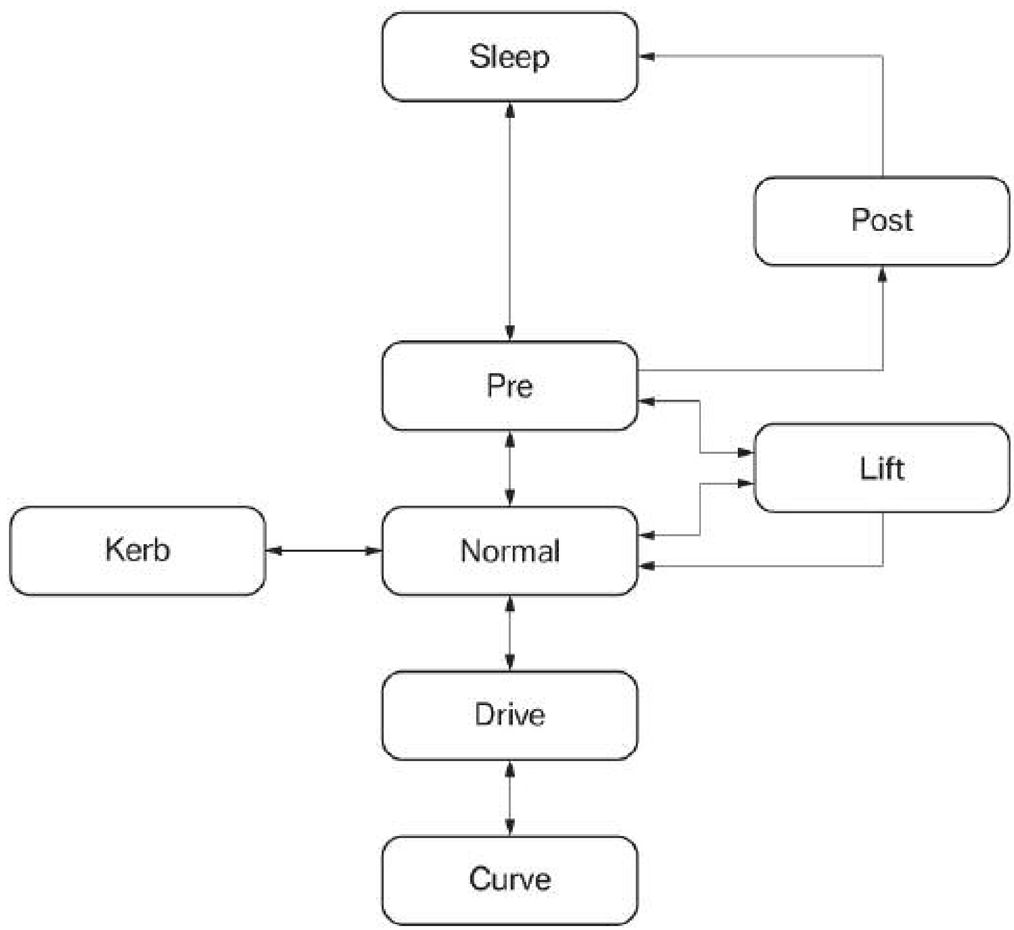
RHS = Ride-height sensor

Electronic Ride-height Control

Function of Air Springs

The various control modes on the F01/F02 are similar to those on other model series such as the E70:

EHC control mode flowchart for F01/F02



Control Modes with Single-axle Air Suspension
Ongoing control operations are not affected by transitions from one mode to another. However, in the case of load cutout OFF (VA_AUS), control operations are always concluded in order to safeguard system deactivation. The EHC control unit then sets Sleep mode.

Important: All technical data quoted are code-specified as at SOP.

Sleep Mode
The vehicle is in Sleep mode at the latest by the time it has been parked for longer than a few minutes without a door or hood/trunk lid being operated or the terminal status changing. This is the initial state of the control system. No control function is performed in Sleep mode. The control system goes into Pre-mode when a wake-up signal is received by the EHC control unit.

Post-mode
Post-mode is activated in order to compensate for any inclination or to adjust the ride height after driving and between the Pre-mode and Sleep mode.

Duration of Post-mode is limited to approximately 1 minute. This mode is only executed if the engine has been running before the system switches into this mode. If the engine has not been running, the system switches directly from Pre-mode to Sleep mode.

Control adjustments are made within a tight tolerance band using the following coding parameters:

Coding parameter	Value
niv_post_up_e	- 59 mm
niv_post_up_d	- 07 mm
niv_post_down_e	+ 06 mm
niv_post_down	+ 04 mm

The fast signal filter is used.

In the event of an inclination (Kerb mode), the control operation takes place for the nominal heights applicable in this situation.

Pre-mode
Pre-mode is activated by the “Load cutout OFF” signal (e.g. in response to opening of the door or unlocking with the radio remote control). The Pre-mode then stays set for 16 minutes and is restarted with a change in status.

The ride height of the vehicle is monitored and evaluated with a wide tolerance band.

In Pre-mode, the vehicle is only controlled up to the nominal height if the level is significantly below the nominal height. This control tolerance ensures that the vehicle is only controlled up in the case of large loads in order to increase the ground clearance prior to departure. Small loads give rise to small compression travel and this is compensated only when the engine is started. This control setting helps to reduce the battery load.

Coding parameter	Value
niv_pre_up_e	- 09 mm
niv_pre_up_d	- 07 mm
niv_pre_down_e	+ 09 mm
niv_pre_down_d	+ 07 mm
niv_pre_mw_up	- 59 mm*
niv_pre_mw_down	0 mm
pre_delay_counter	20 min

* Average figure

With single-axle air suspension, the vehicle is controlled down when the mean value of both ride height signals is > 0 mm and one side is in excess of + 10 mm.

In this mode, only the mean value of the two ride height signals (fast filter) is considered when deciding whether there is a need for a control operation.

There is no inclination detection in Pre-mode.

Normal Mode

Normal mode is the starting point for the vehicle's normal operating state. It is obtained by way of the "Engine running" signal.

Levelling is possible. The compressor starts up as required.

Coding parameter	Value
niv_normal_up_e	- 09 mm
niv_normal_up_d	- 07 mm
niv_normal_down_e	+ 09 mm
niv_normal_down_d	+ 07 mm

A narrower tolerance band than that in Pre-mode can be used because the battery capacity does not have to be protected. The fast filter is used with a narrow tolerance band of ± 10 mm. In this way, ride level compensation takes place outside a narrow tolerance band of ± 10 mm. The faster filter allows the system to respond immediately to changes in ride level. Evaluation and control are performed separately for each wheel.

When a speed signal is detected, the EHC control unit switches into Drive mode. When the vehicle is stopped, the EHC control unit remains in Drive mode. The system switches back into Normal mode only when a door or the luggage compartment lid is also opened. If none of the doors or the luggage compartment lid is opened, the vehicle logically cannot be loaded or unloaded.

This prevents a control operation happening when the vehicle is, for example, stopped at traffic lights and the ride height is above the mean value due to a possible pitching motion at the rear axle.

Drive Mode

Drive mode for the single-axle air suspension is activated when a speed of > 1 km/h is detected.

Coding parameter	Value
niv_drive_up_e	- 07 mm
niv_drive_up_d	- 05 mm
niv_drive_down_e	+ 09 mm
niv_drive_down_d	+ 07 mm

Low-pass filters are used. In this way, only changes in ride height over a prolonged period of time (1000 seconds) are corrected. These are merely the changes in ride height, caused by vehicle compression and a reduction in vehicle mass due to fuel consumption. The high-pass filter (fast filter) is used during the control operation. The slow filters are reinitialized at the end of the control operation. The markedly dynamic height signals caused by uneven road surfaces are filtered out.

Kerb (curb)

Coding parameter	Value
niv_delta_kerb_e	28 mm
niv_delta_kerb_d	24 mm
kerb_delay	<1s

The Kerb mode prevents the inclination caused by the vehicle mounting an obstacle with only one wheel from being compensated. Compensation would cause a renewed inclination of the vehicle and result in a renewed control operation after the wheel came off the obstacle.

Kerb mode is activated if the difference in height between the left and right-hand side of the vehicle is > 24 mm and is present for longer than 0.9 seconds. No speed signal may be present for this mode to be set. The system switches from single-wheel control to axle control.

Kerb mode is quit if the difference between the left and right-hand side of the vehicle is < 28 mm and this difference remains for longer than 0.9 seconds or if the speed is > 1 km/h.

If the system switches from Kerb mode to Sleep mode, this status is stored in the EEP-ROM.

If the vehicle is being loaded or unloaded in Kerb mode, the EHC control unit calculates the mean value for the axle from the changes in ride height determined from the spring travel on the right and left-hand side.

A change in ride level is initiated if the mean value of compression or rebound at the axle is outside the tolerance band of ± 10 mm. The left and right sides of the vehicle are raised or lowered in parallel. The height difference between the two sides is maintained.

Curve
Since rolling motions have a direct impact on the measured ride levels, an unwanted control operation would be initiated during longer instances of cornering with an appropriate roll angle in spite of the slow filtering of the Drive mode. The control operations during cornering would cause displacement of the air volume from the outer side to the inner side of the curve. Once the curve is completed, this would produce an inclination which would result in a further control operation. Curve mode prevents that adjustment by stopping slow filtering when cornering is detected and cancelling any adjustment that may have been started.

Curve mode is activated upwards a lateral acceleration of > 2 m/s2 and deactivated at <

1.0 m/s2. The lateral acceleration is recorded by the DSC sensor.

Substitute conditions:

Coding parameter	Value
time_curve_exit	252 s
niv_delta_curve_e	20 mm
niv_delta_curve_d	16 mm
speed_curve	50 km/h (31 mph)

Lift
The Lift mode is used to prevent control operations when a wheel is changed or during work on the vehicle while it is on a lifting platform.

Coding parameter	Value
niv_lift_up	60 mm
niv_lift_down	Unlimited
kerb_delay	<1s
time_ex_liftdetect	approximately 40 s
speed_lift_exit2	3 km/h

This mode is detected when the permitted rebound travel at one or more wheels is exceeded > 55 mm. A jacking situation is also detected and the ride height stored if the lowering speed drops below the level of 2 mm/ s for 1 second.

If the vehicle is raised only slightly and the permitted rebound travel has not yet been reached, the control operation attempts to readjust the ride height. If the vehicle is not lowered, a car jack situation is recognized after a specific period of time and this ride height is stored.

A reset is performed if the vehicle is again 10 mm below this stored ride height.

Special Modes (Transport, Belt)
Transport mode is set and cancelled by means of diagnostics control. It serves to increase the ground clearance in order to ensure safe transportation of vehicles on transporter trucks. The nominal height of the vehicle is raised in this mode by 30 mm.

When Transport mode is activated, the air suspension symbol is lit on the variable indicator lamp on the instrument cluster and a message is shown on the Check Control display to alert the driver to this special mode.

Control operations do not take place in this mode because the vehicle mass does not change during transportation.

Belt mode is set during assembly in the works to prevent control operations.

When Belt mode is activated, the air suspension symbol is lit in the variable indicator lamp in the instrument cluster and a message is output in the Check Control display to alert the driver to this special mode.

Production-line mode is cleared by means of diagnostics control only. The Belt mode can no longer be set.

New EHC control units (spare part) are supplied with Belt mode set.

Control operations are not performed, the safety concept only operates with limited effect.

Control modes	Single-axle air suspension
Sleep	No control, load cutout on
Post	Approximately 1 minute fast filter 2 s, very narrow tolerance band -59 mm/ -07 mm, control ends at +06/+04 mm
Pre	Approximately 16 minutes fast filter 2 s, wide tolerance band adjusted up at -09 mm, adjusted down at mean value (-59 mm) +09 mm and one side > 10 mm
Normal	Engine running: fast filter 2 s, narrow tolerance band -09 mm/+09 mm
Drive	v > 1 km/h, slow filter 1000 s, narrow tolerance band -07 mm/+07 mm
Kerb	**ON when:** difference between left and right-hand sides of vehicle > 24 mm, longer than 0.9 s changeover from single-wheel control to two-wheel control **OFF when:** difference between left and right-hand sides of vehicle < 28 mm, t = 0.9 s or v > 1 km/h
Curve	**ON when:** lateral acceleration > 2 m/s2 **OFF when:** lateral acceleration < 1.0 m/s2
Lift	**ON when:** rebound travel > 60 mm at one or more wheels **Jack on at:** lowering speed drops below 2 mm/s for 1 s, ride height stored **OFF when:** level change < -10 mm, ride height drops below stored setting by more than 10 mm

Method of Operation

Initialization/reset behavior

Different checks and initializations are carried out when the EHC control unit is powered up after a reset (triggered by an undervoltage or also by load cutout off VA_AUS).

The system is only enabled after the tests have been successfully completed and starts to execute the control programs on a cyclical basis. Occurring faults are stored and displayed.

Control sequence

In an ongoing control operation, the high-pass filter (fast filter) is always used to prevent the controlled height from overshooting the specified setting.

If a low-pass filter (slow filter) were used to calculate the ride height, brief changes of ride height would be "absorbed".

The low-pass filter is used when the vehicle is in motion (see Normal mode) to filter out vibrations induced by prevailing road conditions on this basis of this method of filtering.

The high-pass filter is used to respond quickly to ride level deviations from setpoint. These take place while the vehicle is stationary in the event of large load changes (see Pre-mode).

Both sides of the vehicle are controlled individually, i.e. even the setpoint/actual-value comparison for both sides is carried out individually.

Exception: check for falling below the minimum height in Pre-mode and Kerb mode. The left/right mean values are taken into consideration here. The following stipulations are applicable here:

- Raising or lowering
- All valves controlled with control in the same direction
- Individual wheel deactivation

To ensure reliable closing of the non-return valve in the air drier, the exhaust valve is operated briefly for 200 ms by the EHC control unit after each control sequence.

The permissible ON period is monitored while performing upward adjustment operations.

Safety concept

The safety concept is intended to inhibit any system malfunction, particularly unintentional control operations, through the monitoring of signals and function-relevant parameters.

If faults are detected, the system is switched over or shut down depending on the components concerned. The driver is informed of any faults by the display, and detected faults are stored for diagnostic purposes.

In order to ensure high system availability, existing faults, as far as possible, are cleared with terminal 15 ON.

This is done by resetting the logistics counter to zero. However, the fault memory content in the EEPROM is retained and can be read out for diagnostic purposes. The system is then operational again. Fast fault detection means that existing faults are detected before control operations can take place.

Only lowering is permitted if:

- the power supply voltage drops below the permissible minimum of 9 volts.
- the permissible compressor duty periods, and therefore compressor temperatures, based on a temperature duty period algorithm* are exceeded.

A reset is carried out if the voltage is within the required range of 9 to 16 volts or after expiry of the compressor pause period of approximately 100 seconds.

Only raising is permitted if:

- The permissible control down period of 40 seconds is exceeded.
- The reset takes place the next time the vehicle is driven or after the next control-up procedure.

No control if:

- The permissible supply voltage of 16 volts is exceeded.

The reset takes place as soon as the voltage is within the required range.

*** Temperature duty period algorithm:**
In order to prevent overheating problems when the compressor is running or when outside temperatures are very high, a temperature duty period algorithm has been implemented.

T_{Start} (starting temperature) is assumed from the coil resistance of the exhaust valve and the theoretical temperature change is calculated on the basis of the change in coil resistance.

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Electronic Ride-height Control (EHC)

Control Unit

The EHC control unit is located in a module carrier in the rear of the luggage compartment on the right-hand side.

Rear right module carrier

Index	Explanation	Index	Explanation
1	Air supply (LVA)	2	EHC control module on mounting bracket

The EHC control unit is fully compatible with diagnostics.
The EHC control unit receives the following signals:

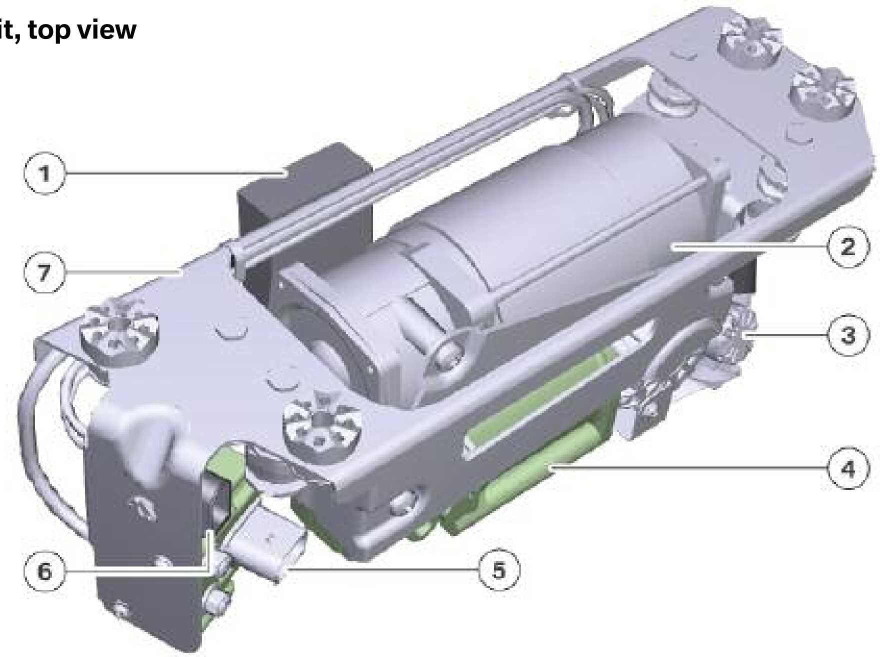
- Vehicle ride height
- Load cutout signals
- Terminal 15 ON/OFF
- Vehicle speed
- Lateral acceleration
- “Engine running” signal
- Hatch status.

The EHC control unit decides on a case-by case basis whether a control operation is required in order to compensate for changes in load.

It is thus possible to optimally adapt the frequency, specified heights, tolerance thresholds and battery load to the relevant situation by means of the control operation.

Air Supply Unit (LVA)

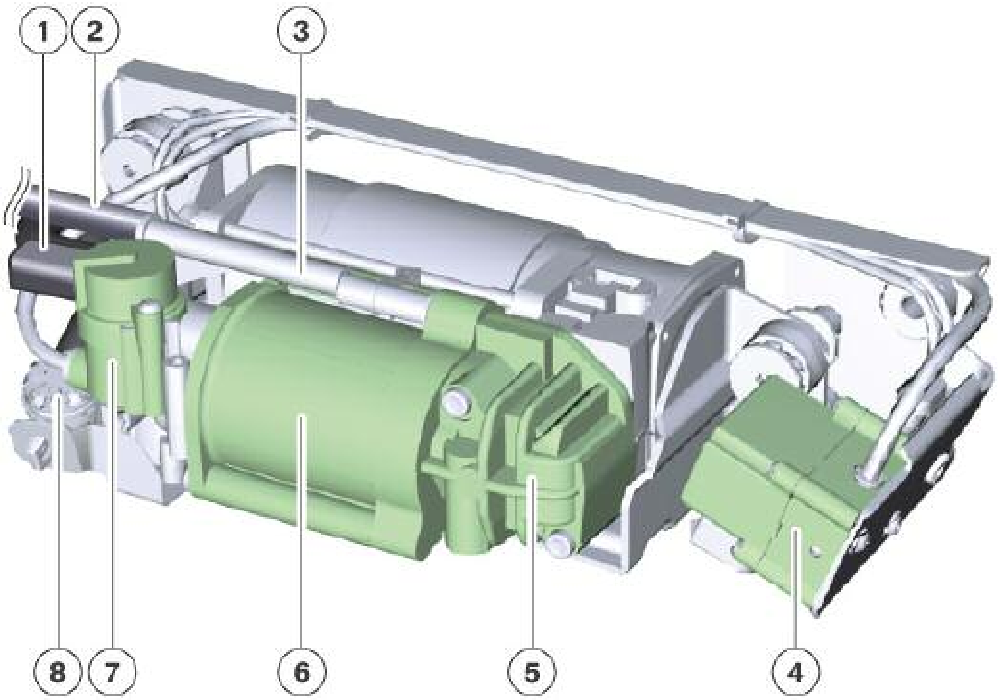
Air supply unit, top view



Index	Explanation	Index	Explanation
1	Compressor relay	5	Electrical connector, 3-pin, for valve manifold
2	Electric motor	6	Electrical connector, 2-pin, for electric motor
3	Air exhaust silencer	7	Component carrier
4	Air drier		

The air supply unit is mounted at the rear of the vehicle on the trunk floor.

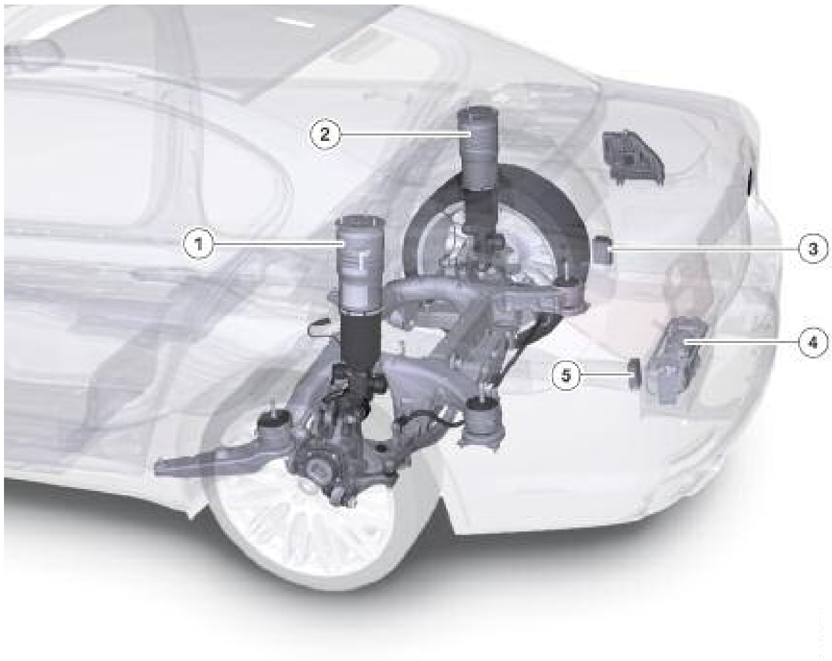
Air supply unit, bottom view



Index	Explanation	Index	Explanation
1	Electrical connector, 2-pin, for exhaust valve	5	Compressor
2	Air intake line to left rear light unit	6	Air drier
3	Air intake	7	Air exhaust valve
4	Valve block	8	Air exhaust silencer

Air Suspension

Components in the vehicle



Index	Explanation	Index	Explanation
1	Left air spring strut	4	Air supply unit
2	Right air spring strut	5	Compressor relay
3	EHC control unit		

Ride-height Sensor

Index	Explanation
1	Electrical connector
2	Sensor housing
3	Lever

The angle of a pivoting lever is converted into a voltage signal by the ride height sensor. The greater the angle (relative to a defined starting or zero position), the greater is the output voltage. It is generated by a Hall-effect sensor element.

Designs

There are always four ride-height sensors fitted on all F01/F02 models.

The ride-height sensors fitted all operate according to the same principle but there are different designs (different part numbers). The reason for the differences are the available space and the starting position (zero position) of the individual ride-height sensors.

Depending on whether or not the vehicle is fitted with Electronic Height Control (EHC), double or single ride-height sensors are fitted on the rear suspension.

On the front suspension, single ride-height sensors are always used.

	Front suspension	Rear suspension
EHC, not fitted	Single RHS	Single
EHC, fitted	Single RHS	Double